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Report to the Space Science Board

on the

SPACE SCIENCE AND

SATELLITE APPLICATIONS PROGRAMS

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SPACE SCIENCE AND SATELLITE APPLICATIONS PROGRAMS

Prepared for the Space Science Board

by

Dr. H. E. Newell

Director, Office of Space Sciences

NASA Headquarters

December 1962

SPACE SCIENCE AND SATELLITE APPLICATIONS PROGRAMS

PAST ACCOMPLISHMENTS

The following is a list of the successful major satellite and space probe firings that have been carried out in connection with the NASA program since the creation of NASA in 1958:

PIONEER I	Magnetic field, radiation belts
PIONEER II	Magnetic field, radiation belts, cosmic rays
PIONEER III	Radiation belts, cosmic rays
VANGUARD II	Cloud cover
PIONEER IV	Radiation belts, cosmic rays
EXPLORER VI	Magnetic field, radiation belts
VANGUARD III	Magnetic Field
EXPLORER VII	Radiation belts, cosmic rays, thermal radiation, micrometeors
PIONEER V	Magnetic field, cosmic rays
TIROS I	Cloud cover
ECHO I	Air density
EXPLORER VIII	Ionosphere, micrometeors
TIROS II	Cloud cover, thermal radiation
EXPLORER IX	Air density
EXPLORER X	Magnetic field, plasma
EXPLORER XI	Gamma radiation
TIROS III	Cloud cover, thermal radiation
EXPLORER XII	Magnetic field, radiation belts, cosmic rays
EXPLORER XIII	Micrometeors
TIROS IV	Cloud cover, thermal radiation
OSO I	Electromagnetic radiation from sun
ARIEL I	Ionosphere, radiation
TIROS V	Cloud cover
TELSTAR I	Active communications
ECHO II	Passive communications

MARINER II	Particles and fields, cosmic dust, Venus IR and microwave radiation
TIROS VI	Cloud cover
ALOUETTE	Ionospheric topside sounding, radio noise, cosmic rays
EXPLORER XIV	Energetic particles, magnetic field, cosmic rays
EXPLORER XV	Art. [illegible] Radiation belts

PLANNED FLIGHT SCHEDULE (As of 15 October 1962)

	CY-'62	CY-1963				CY-1964			
	4th. Qtr.	1st. Qtr.	2nd. Qtr.	3rd. Qtr.	4th Qtr.	1st. Qtr.	2nd. Qtr.		
Geophysics & Astronomy									
Observatories									
OSO			X		X		X		X
OAO									X
OGO (EGO					X		X		
(POGO						X		X	
Explorers & Monitors									
Energetic Particles Monitor					X		X		X
Atmospheric Structures Explorer		X	X						
Ionosphere Explorer			X			X			
International		XX	X	XX				X	X
Lunar & Planetary									
Ranger		X	XX	X		X	XX	XX	
Surveyor Lander								X	X
Mariner R						XX			
Mariner C.									XX
Applications									
Communications									
Echo		X							
Relay	X		X	X					
Syncom		X	X	X					
Telstar			X	X					
Meteorology									
Tiros		X	X						
Nimbus (R&D)				X			X		
Nimbus (Oper.)								X	X

EXPERIMENTS AND EXPERIMENTERS FOR FORTHCOMING MISSIONS

The experiments and experimenters for forthcoming missions are described in the following sections.

Orbiting Geophysical Observatories

Orbiting Solar Observatories

Orbiting Astronomical Observatories

Interplanetary Monitoring Probe

International Satellites

Ranger

Surveyor

Mariner

Orbiting Biological Observatories

ORBITING GEOPHYSICAL OBSERVATORIES

The Orbiting Geophysical Observatories (OGO) are a series of standardized spacecraft capable of accommodating thirty or more scientific experiments in various orbits reaching far from the earth. Two types are planned:

(1) The Eccentric Orbiting Geophysical Observatory (EGO) will be placed in a highly eccentric orbit reaching from a perigee of 170 miles to an apogee of 69,000 miles. It will be useful for investigations beyond the geomagnetic field, within the field, and within the Van Allen radiation belts.

(2) The Polar Orbiting Geophysical Observatory (POGO) will be launched into near-earth polar orbits (160 to 570 mile polar orbits). POGO will emphasize the investigation of the phenomena of the polar regions, such as the radiation belt "horns", auroral activity, low energy cosmic rays, the geomagnetic field, the ionosphere, and anomalous temperature and density changes.

The EGO spacecraft will weigh approximately 1,000 pounds, of which 150 pounds is allotted to experiments. The first EGO is scheduled to be launched with an Atlas-Agena during 1963 from AMR.

The first POGO is scheduled for launch with a Thor-Agena during 1964 from PMR. It, too, will weigh about 1,000 pounds, of which 150 has been allotted to scientific experiments.

Spacecraft design, development, fabrication, assembly, integration of experiments, and test and evaluation are being carried out under contract by the Space Technology Laboratories, Los Angeles, California. Essentially all subcontracts for the first EGO and first POGO have been let.

The current design for the OGO spacecraft calls for a body about 2-3/4 ft x 2-3/4 ft x 5 ft containing portions of the stabilization control, power supply, communications, and data handling and thermal control systems, as well as space for experiments. The power supply system consists of solar cell panels, nickel cadmium batteries, and a charge control system. A maximum power of 414 watts and an average power of 250 watts will be available. Maximum power allocated to scientific experiments is 80 watts and the average power is 50 watts. Angular orientation of the spacecraft is accomplished through torques developed by motor-driven inertial flywheels and by gas jets. Deviations of the spacecraft from the sun axis are sensed by solar cells; deviations from the earth's local vertical are determined by horizon scanners. Thermal control is accomplished by use of radiation shields and louvers. The data processing and communications system accepts ground commands to program experiments, to vary transmission rates, and to apportion information bits to the data generated by the experiments and by vehicle performance parameters. Storage of 84 million bits of data is possible by use of two magnetic tape recorders. Two redundant wideband telemetry transmitters in the spacecraft are capable of sending experimental and spacecraft data back to earth, either in real time, on command, or from storage.

The following are the final lists of experiments and experimenters for the first EGO and the first POGO.

FIRST EGO SPACECRAFT

Experiments and Experimenters

1. Solar cosmic rays, 10-90 Mev, using a scintillation detector to measure fluxes.

   K. A. Anderson
   University of California (Berkeley)

2. Positron and gamma ray detection, using double gamma ray spectrometer to measure positrons (0 to 3 Mev) and to monitor solar photon bursts.

   T. L. Cline and E. W. Hones, Jr.
   Goddard Space Flight Center

3. Trapped radiation studies, with ion-electron scintillation detector, of trapped electrons with directional energy flux, 10 Kev$<E<$100 Kev, and protons with directional intensity, 120 Kev$<E<$4.5 Mev.

   L. R. Davis
   Goddard Space Flight Center

4. Galactic cosmic rays and isotope abundance with cosmic ray telescope.

   F. B. McDonald and D. A. Bryant
   Goddard Space Flight Center

5. Low energy galactic cosmic ray flux, using charged particle telescope to study protons above 0.2 Mev and other nuclei at higher energies.

   J. A. Simpson, C. Y. Fan and P. Meyer
   University of Chicago

6. Trapped radiation, using Geiger tubes to measure omnidirectional intensities of outer belt electrons exceeding 40 Kev, 120 Kev, and 1.5 Mev.

   J. A. Van Allen and L. A. Frank
   State University of Iowa

7. Trapped radiation, using spectrometer to measure electron energy up to 4 Mev.

   J. A. Winckler and R. L. Arnoldy
   University of Minnesota

8. Fluctuations in vector magnetic field in frequency range 0.01 to 1000 cps using triaxial search coil magnetometer.

E. J. Smith — Jet Propulsion Laboratory
R. E. Halzer — U. C. L. A.

9. Rubidium vapor magnetometer to measure magnitude and direction of magnetic fields over the range 1 to 100 gammas.

J. P. Heppner
Goddard Space Flight Center

10. Electrostatic analyzer used as plasma proble to measure proton concentrations (10^{-2} to 10^{-4} particles per cm^3) as a function of proton energy, 0.2 to 20 Kev.

M. Bader
Ames Research Center

11. Proton and electron Faraday cup plasma probes to measure proton flux and energy spectrum, and their variations, in the energy range, 10 ev to 10 Kev.

H. Bridge, A. Bonetti, B. Rossi, A. J. Lazarus, F. Scherb
Massachusetts Institute of Technology

12. Spherical ion and electron ion trap to measure concentration and energy distribution of charged particles in energy range 0 to 1.0 Kev.

R. C. Sagalyn and M. Smiddy
Air Force Cambridge Research Institute

13. Planar ion and electron trap to obtain densities and energy distributions of charged particles of both polarities in the low energy or thermal range.

E. C. Whipple, Jr.
Goddard Space Flight Center

14. VLF noise and propagation at frequencies of 200 to 100,000 cps.

R. A. Helliwell and L. H. Rordan
Stanford University

15. Radio astronomy in frequency band 2 to 4 Mc, primarily to measure the dynamic radio spectra of solar bursts.

F. T. Haddock
University of Michigan

16. Radio beacon to radiate linearly polarized signals (40 and 360 Mc) toward the earth to measure number of electrons beneath the satellite.

R. S. Lawrence and H. J. A. Chivers
National Bureau of Standards (CRPL)

17. Ion mass spectrometry to obtain direct measurements of positive ion composition in the range 1-50 AMU.

H. Taylor and N. W. Spencer
Goddard Space Flight Center

18. Micrometeoroids; vector velocity distribution, cumulative mass distribution, effect of geocentric distance.

W. M. Alexander and C. W. McCracken
Goddard Space Flight Center

19. Lyman-alpha scattering in the geocorona and the interplanetary medium.

P. M. Mange
Naval Research Laboratory

20. Back-up experiment. Geogenschein photometry in ultraviolet, green and infrared regions.

C. L. Wolff
Goddard Space Flight Center

FIRST POGO SPACECRAFT

Experiments and Experimenters

1. Radioastronomy measurements of galactic emission at 2.5 and 3.0 Mc/s

   F. T. Haddock
   University of Michigan

2. VLF measurements of terrestrial and other emissions in the frequency range, o.2 to 100 Kc.

   R. A. Helliwell
   Stanford University

3. VLF terrestrial and other emissions at 0.5 to 10 Kc

   M. G. Morgan and T. L. Laaspere
   Dartmouth College

4. Relationship between VLF emissions and high energy electron bunches from 5 to 100 Kev.

   J. A. Winckler — University of Minnesota
   R. M. Gallet — National Bureau of Standards (CRPL)

5. Magnetic field fluctuations in the low audiofrequency range using search coil magnetometers.

   R. E. Holzer — University of California (L. A.)
   E. J. Smith — Jet Propulsion Laboratory

6. World magnetic survey with rubidium-vapor and helium magnetometers

   J. P. Heppner, H. R. Boroson and J. C. Cain
   Goddard Space Flight Center

7. Comparison of ionization over polar regions with that measured by space probes (such as Mariner, Ranger, etc.)

   H. V. Neher — California Institute of Technology
   H. Anderson — Jet Propulsion Laboratory

8. Determination of nucleons, 0.3 to 30 Mev, by means of a scintillation telescope.

   J. A. Simpson
   University of Chicago

9. Energy spectrum and charge particle composition of galactic and solar cosmic rays as observed with a modified Cerenkov detector.

W. R. Webber
University of Minnesota

10. Net downflux of corpuscular radiation in the auroral zones and over the polar caps, using Geiger tubes as detectors.

J. A. Van Allen
State University of Iowa

11. Low energy trapped radiation and auroral particles (electrons, 10-100 Kev; protons, 100 Kev to 4.5 Mev) as observed with scintillation detector.

R. A. Hoffman, L. R. Davis, A. Konradi, and J. M. Williamson
Goddard Space Flight Center

12. Photometer airglow measurements at 6300A, 5577A, 3914A, and in the near ultraviolet region.

J. Blamont — University of Paris
E. I. Reed — Goddard Space Flight Center

13. Airglow studies in the Lyman-alpha, far ultraviolet, and 1230A-1350A regions with UV ion chamber.

P. M. Mange, T. A. Chubb and H. Friedman
Naval Research Laboratory

14. Ultraviolet spectrometer for airglow measurements between 1100A and 3400A

C. A. Barth — Jet Propulsion Laboratory
L. Wallace — Yerkes Observatory

15. Paul massenfilter mass spectrometer for neutral particle and ion composition in the mass ranges 0-6 AMU and 0-40AMU

L. M. Jones and E. J. Schaefer
University of Michigan

16. Bennett RF ion mass spectrometer for mass ranges 1-6 AMU and 7-45 AMU

H. A. Taylor, Jr. and H. C. Brinton
Goddard Space Flight Center

17. Density of neutral particles with Bayard-Alpert ionization gage.

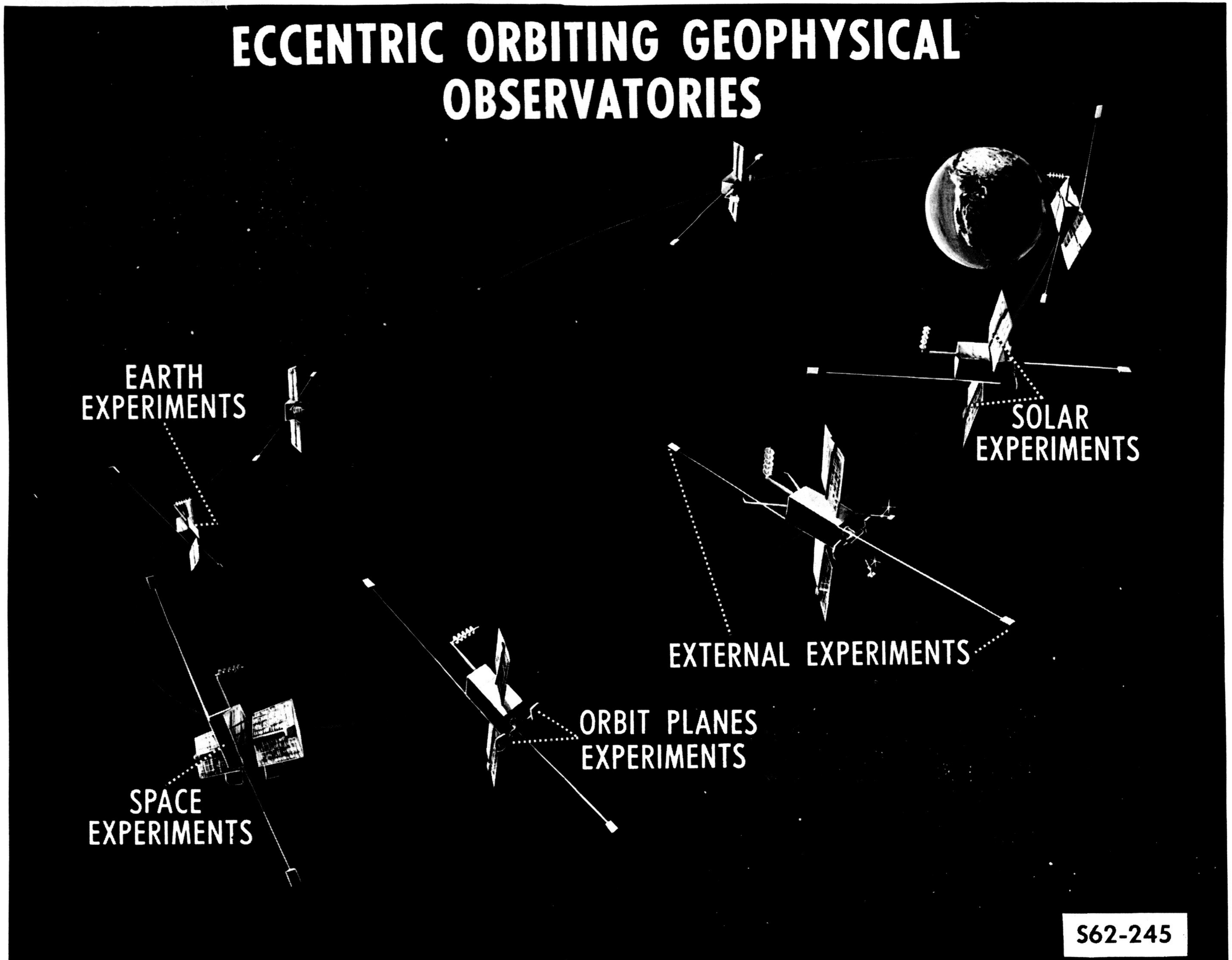
G. P. Newton
Goddard Space Flight Center

18. Micrometeorites; spatial density, mass distribution, velocity, and charge.

W. M. Alexander, C. W. McCracken, O. E. Berg, L. Secretan
Goddard Space Flight Center

19. Ionosphere charged particles and solar UV radiation observed with a combined retarding-potential analyzer.

R. E. Bourdeau
Goddard Space Flight Center


ECCENTRIC ORBITING GEOPHYSICAL
OBSERVATORIES
EARTH EXPERIMENTS
SOLAR EXPERIMENTS
EXTERNAL EXPERIMENTS
ORBIT PLANES EXPERIMENTS
SPACE EXPERIMENTS
S62-245

ORBITING SOLAR OBSERVATORIES

The Orbiting Solar Observatories (OSO) are a series of stablilzed space platforms designed primarily for solar oriented experiments. The spacecraft consists of a rotating wheel-like structure, containing nine wedge-shaped compartments for instrumentation, connected to a fan-shaped stabilized section by a shaft. The oriented portion of the spacecraft points continuously at the center of the sun with an accuracy somewhat less than 2 minutes. The wheel experiments are in general sky mapping experiments comparing radiation from the sun to that in other portions of the sky. The observatories are launched from AMR by Thor-Delta vehicles and are intended to orbit the earth in a circular orbit at an altitude of 300 miles.

The first Orbiting Solar Observatory, OSO I, was launched successfully on March 7, 1962 and returned useful, unique data concerning the sun during eleven weeks of continuous operation and several additional weeks of intermittent operation.

The second OSO will be launched in the second quarter of 1963, and the third, in the fourth quarter of 1963. The second and third OSO's will carry the following experiments:

SECOND OSO SPACECRAFT

Experiments and Experimenters

1. Ultraviolet spectrometry in the ranges, 75-600A and 500-1500A.

   W. Lillier, L. Goldberg
   Harvard University

2. Solar X-ray bursts in the 8-20A and 44-66A regions.

   T. A. Chubb, R. Kreplin
   Naval Research Laboratory

3. White light coronagraph

   R. Tousey, J. Purcell
   Naval Research Laboratory

4. Solar scan in the Lyman-alpha region

   R. Tousey, J. Purcell
   Naval Research Laboratory

5. Intensity and direction of polarized light from interplanetary space.

   E. P. Ney
   University of Minnesota

6. Arrival direction and energies of primary cosmic rays, 50-1000 Mev

C. P. Leavitt
University of New Mexico

7. Gamma ray energy spectrum, 0.1 to 5 Mev

K. J. Frost
Goddard Space Flight Center

8. Ultraviolet stellar and nebular spectrophotometry in the region, 900-3800A

K. L. Hallam, W. A. White
Goddard Space Flight Center

9. Emissivity stability of surfaces in a vacuum environment

G. G. Robinson, C. B. Neel
Ames Research Center

THIRD OSO SPACECRAFT

Experiments and Experimenters

1. Monochromator measurements of solar extreme ultraviolet.

   H. E. Hinteregger
   Air Force Cambridge Research Laboratories

2. Emissivity stability of low temperature coatings.

   C. B. Neel, G. G. Robinson
   Ames Research Center

3. Earth albedo in the ultraviolet and visual regions.

   C. B. Neel, G. G. Robinson
   Ames Research Center

4. X-ray and gamma ray astronomy

   L. E. Peterson
   University of California, La Jolla

5. Studies of the solar spectrum from 1 A to 400 A

   W. E. Behring, W. A. White, W. M. Neupert, J. C. Lindsay
   Goddard Space Flight Center

6. Gamma ray astronomy

   W. L. Kraushaar
   Massachusetts Institute of Technology

7. Solar X-rays

   R. G. Teske
   University of Michigan

8. Solar gamma rays

   E. M. Hafner, M. F. Kaplon
   University of Rochester

Alternate Experiments and Experimenters

1. Proton-Electron Measurements

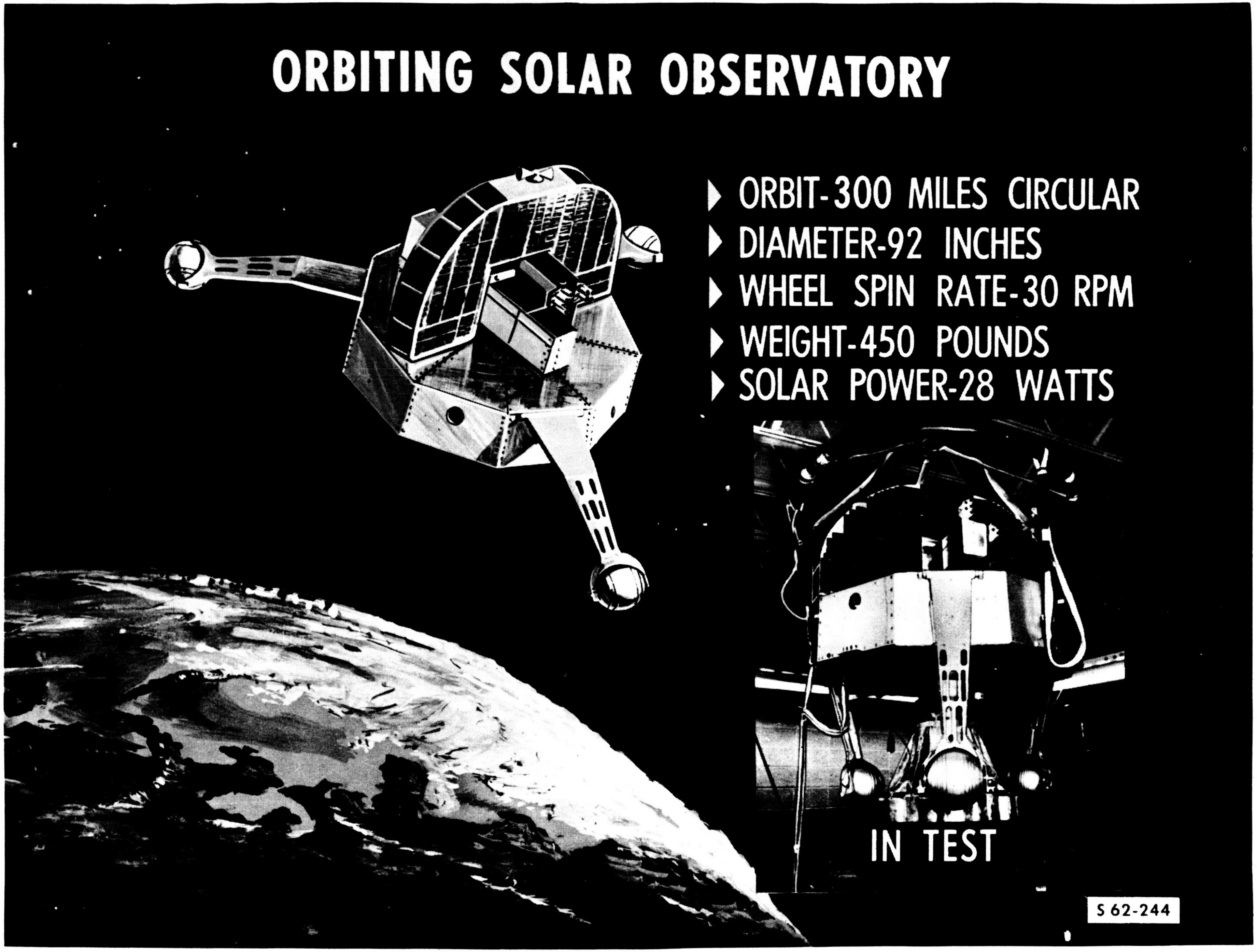
   S. D. Bloom, E. Schrader
   UCLRL

2. Solar X-ray Spectrocopy

   H. Friedman, T. A. Chubb
   Naval Research Laboratory

3. Solar X-ray Measurements

   R. Tousey, T. A. Chubb
   Naval Research Laboratory


ORBITING SOLAR OBSERVATORY
ORBIT-300 MILES CIRCULAR
DIAMETER-92 INCHES
WHEEL SPIN RATE-30 RPM
WEIGHT-450 POUNDS
SOLAR POWER-28 WATTS
IN TEST
S 62-244

ORBITING ASTRONOMICAL OBSERVATORIES

The Orbiting Astronomical Observatories (OAO) are designed for the exploration of those regions of the spectrum that are now inaccessible because of atmospheric absorption. The OAO is a precisely-stabilized satellite designed to accommodate astronomical observing equipment. The primary experiments for the first three observatories are all concerned with stellar astronomy in the ultraviolet range (800 to 4000 Å).

1. The first OAO will carry two prime experiments:

   a. A mapping study of the celestial sphere in three ultraviolet ranges. This experiment will map the sky in ultraviolet down to a wavelength of 1100 Å with three broad band television photometers and will record the brightness of some 200,000 stars.

   b. A broad band photometry study of individual stars and nebulae. These observations will be directed toward the determination of the stellar energy distribution in the spectral region from 800 to approximately 3000 Å, and the measurement of emission line intensities of diffuse nebulae in the same spectral region. These investigations are expected to provide data which will serve as an aid in designing later instrumentation in addition to their astronomical value.

2. The second OAO will contain a system designed to obtain absolute spectrophotometric data on selected stars, nebulae and galaxies. The optical system will employ a relatively fast 36-inch Cassegrain telescope with a large aperture spectrophotometer and will use both the coarse (1 minute of arc) and the fine (1 second of arc) control systems. The usable spectral region will be approximately 912 to 4000 Å.

3. The absorption experiment in the third observatory has, as its primary objective, quantitative observations of the absorption spectrum of the interstellar gas in the regions between 800 and 1500 Å and 1600 and 3000 Å.

It is expected that later satellites will be used for studies of the sun and planets. In addition, all observatories will have a limited amount of payload capacity for small secondary experiments.

The present concept of the OAO spacecraft is being developed by the Grumman Aircraft Engineering Corporation, Bethpage, L.I., N.Y. The basic structure is octagonally-shaped with a central tubular area containing the experimental equipment. The total weight of the spacecraft is expected to be about 3300 lbs., of which 1000 lbs. is allocated to the experimental apparatus.

The power supply for OAO is externally-mounted fixed arrays of silicon solar cells used in conjunction with rechargeable nickel-cadmium storage batteries. An average power of 215 watts is available from the arrays. The power available to the experimental equipment is to be 30 watts average and 60 watts peak.

The stabilization and control system consists of star trackers, sun trackers, inertial wheels, and gas jets. The requirements imposed on the guidance and control system will permit determination of the absolute direction of the optical axis to an accuracy of one minute of arc and orientation of the optical axis to one degree with respect to a known reference. Also, the control system will permit an ultimate guiding accuracy of 0.1 second of arc during observation of an individual star. The major function of the attitude control system may be categorized as follows:

1. To stabilize the spacecraft following booster separation and to establish its attitude with the required precision.

2. To slew the satellite to any desired attitude as dictated by the scientific objectives of the mission.

3. To enable the satellite to maintain a given attitude with the required accuracy for long periods of time.

The remainder of the basic system is comprised of data storage units and a communications system, including four radio links which are required to accomplish tracking, command, and telemetry.

The satellite will be launched by an Atlas-Agena-B from AMR into an approximately circular orbit at an altitude of 500 statute miles, inclined to the equator at an angle of 32 degrees.

ORBITING ASTRONOMICAL OBSERVATORIES

OAO-1, OAO-2, OAO-3

Experiments and Experimenters

OAO-1

Mapping in three ultraviolet ranges

F. Whipple
Smithsonian Astrophysical Observatory

Stellar broad band photometry measurements in ultraviolet

A. Code
University of Wisconsin

OAO-2

Absolute spectrophotometry measurements

J. Milligan
Goddard Space Flight Center

OAO-3

Interstellar absorption measurements

L. Spitzer
Princeton University


ORBITING ASTRONOMICAL OBSERVATORY
ULTRAVIOLET LIGHT
FROM STARS
INITIAL OBJECTIVES
DETAILED MAP OF THE SKY
IN ULTRAVIOLET LIGHT
DEVELOP A STANDARD
SPACE OBSERVATORY
GROUND BASED
OBSERVATORIES;
BLINDED TO ULTRA-
VIOLET LIGHT BY
EARTH'S ATMOSPHERE
OAO MOCK UP

INTERPLANETARY MONITORING PROBES

The interplanetary monitoring probes have been developed for the purposes suggested by their name. They belong to the general group of small satellites and will be put in orbit with the Delta vehicle. The planned orbit calls for an apogee of 180,000 miles and a perigee of 110 miles and a small angle of inclination (31^{o}). The first interplanetary monitoring probe will carry the following experiments.

FIRST INTERPLANETARY MONITORING PROBE

Experiments and Experimenters

1. Magnetic field measured with rubidium vapor and fluxgate magnetometers

    N. F. Ness
    Goddard Space Flight Center

2. Plasma measurements in energy range of a few electron volts to 8 Kev

    H. S. Bridge
    Massachusetts Institute of Technology

3. Energetic particles in energy range, 10 to 200 Mev

    J. A. Simpson
    Chicago University

4. Plasma measurements in thermal energy range (0-10 Ev)

    G. P. Serbu
    Goddard Space Flight Center

5. Total charged particle flux
    K. A. Anderson
    University of California, Berkeley

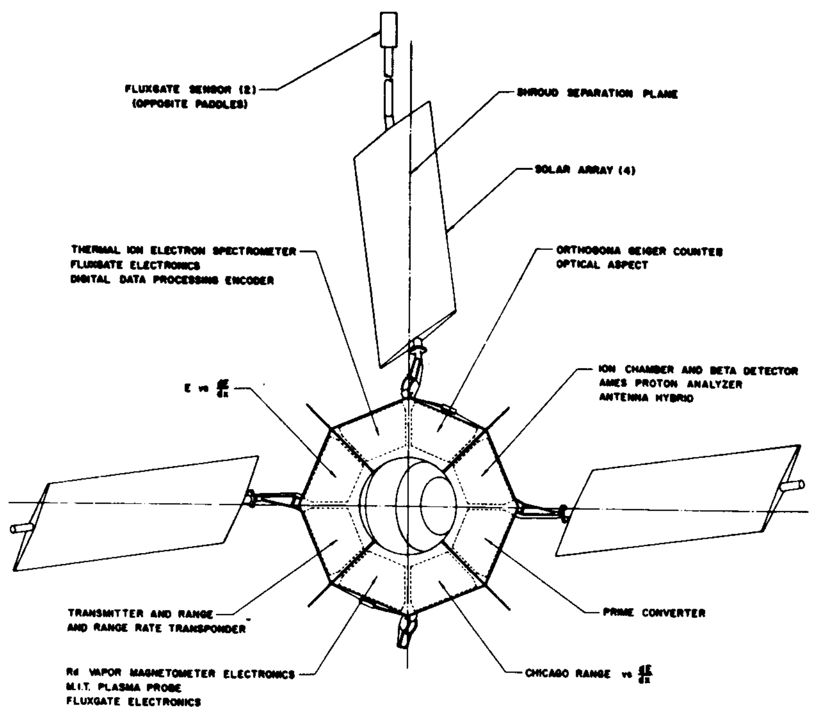
6. Total energy of protons versus energy loss over range, 10 to 100 Mev

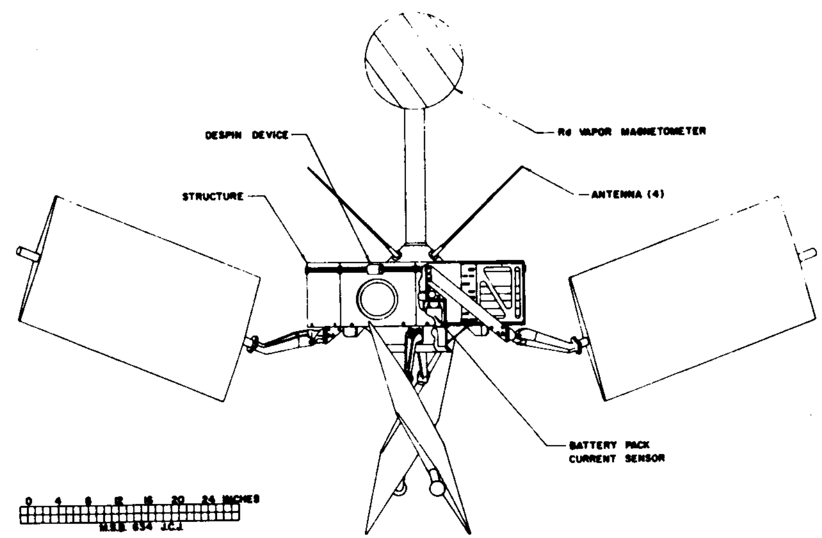
    F. B. McDonald
    Goddard Space Flight Center

7. Proton analyzer

    M. Bader
    Ames Research Center

S-74 INTERPLANETARY MONITORING PROBE





INTERNATIONAL SATELLITES

A number of satellites are programed that call for international cooperation with either national units of scientists or with individual scientists. These satellites are:

1. A second United Kingdom satellite (ARIEL, International Ionosphere Satellite, was the first) - First releases of information concerning the experiments to be carried aboard the UK #2 indicate the following:

   a. A galactic radio noise study in the frequency range between 0.75 to 3.0 megacycles and exploration of the upper atmosphere.

      - F. G. Smith of the University of Cambridge

   b. A study of the vertical distribution of ozone in the atmosphere using filtered photocells and a prism spectrometer in the region from 2500 to 4000A.

      - R. Frith and K. A. Stewart of the UK Air Ministry

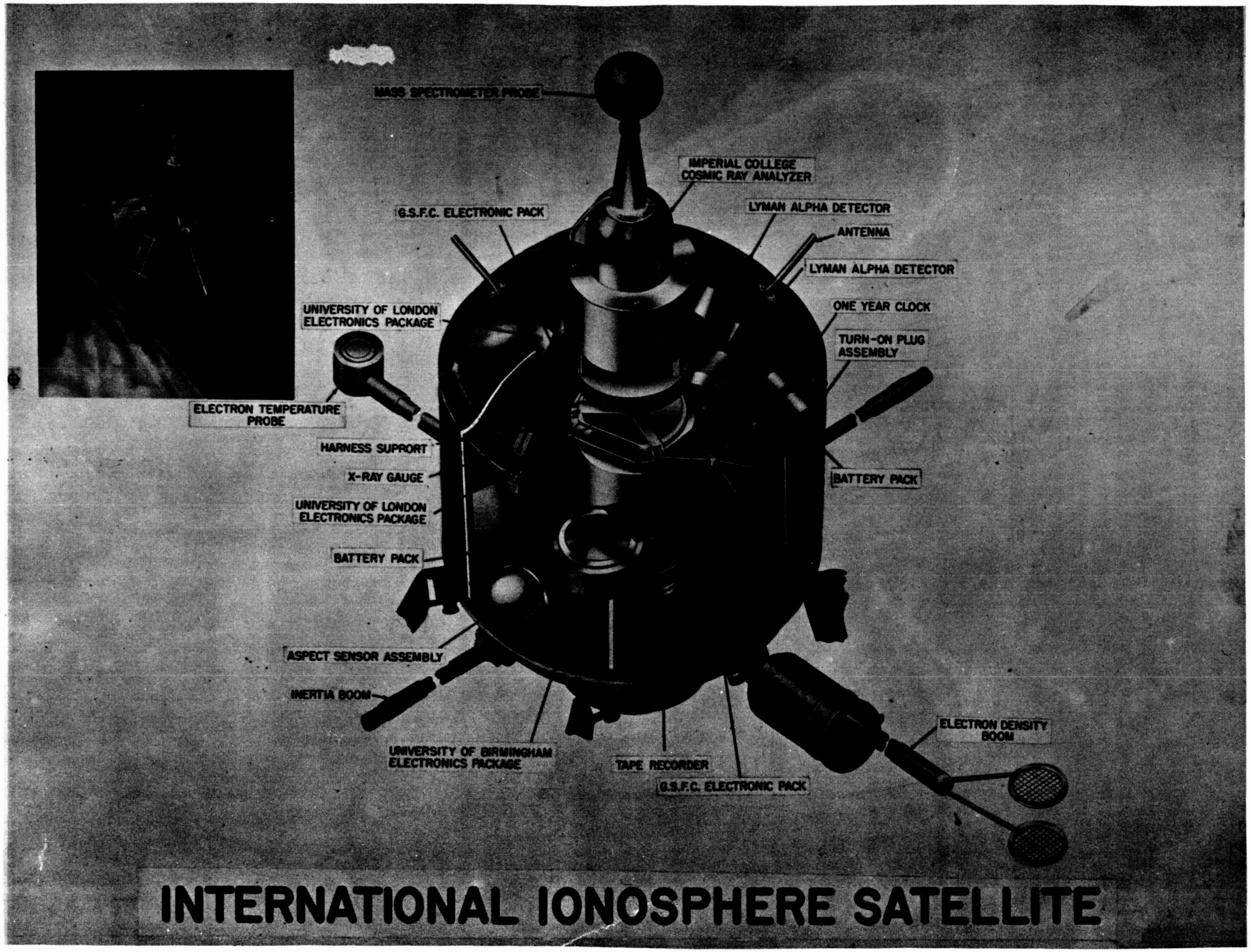
   c. A study of micrometeorite flux; the quantity and size of particles down to several microns studied by the holes formed in thin metallic films.

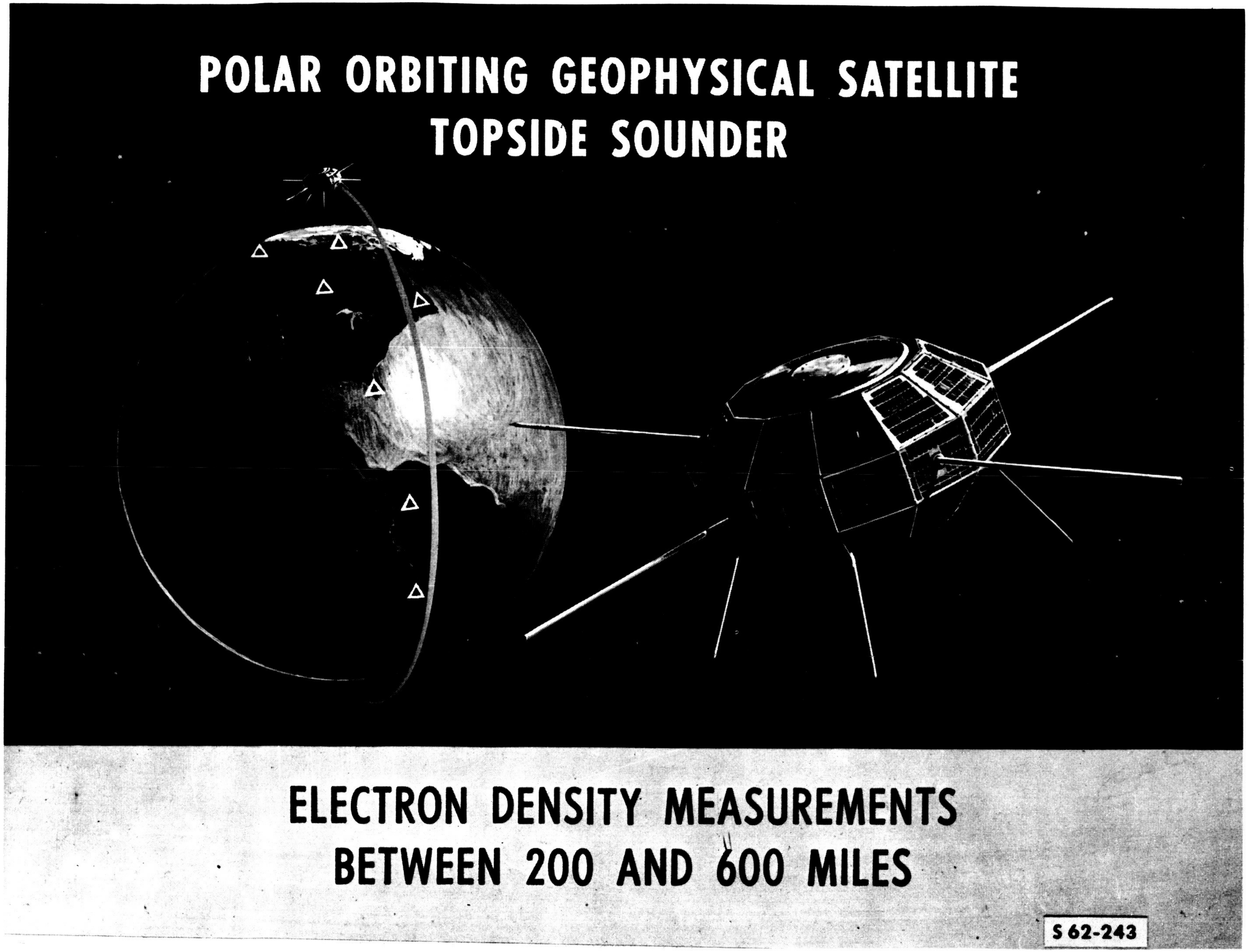
      - R. C. Jennison and J. Bank of the Nuffield Radio Astronomy Laboratories

   Experiments have not been announced for the third UK satellite.

2. Polar Ionosphere Beacon - The primary objectives of the experiments on the satellite will be to determine the general profile of the ionosphere, its irregularities, and the propagation characteristics below the altitude of the satellite as these characteristics affect radio communication frequencies. This program offers an opportunity for world-wide cooperation. Foreign observers will be given orbital data necessary to conduct experiments with the beacon radio frequencies from the satellite.

In addition the first Canadian satellite, Alouette, (Polar Orbiting Geophysical Satellite, Topside Sounder) was flown in 1962. Future Canadian satellites are also being contemplated.


MASS SPECTROMETER PROBE
IMPERIAL COLLEGE COSMIC RAY ANALYZER
G.S.F.C. ELECTRONIC PACK
LYMAN ALPHA DETECTOR
ANTENNA
LYMAN ALPHA DETECTOR
ONE YEAR CLOCK
TURN-ON PLUG ASSEMBLY
UNIVERSITY OF LONDON ELECTRONICS PACKAGE
ELECTRON TEMPERATURE PROBE
HARNESS SUPRORT
X-RAY GAUGE
UNIVERSITY OF LONDON ELECTRONICS PACKAGE
BATTERY PACK
BATTERY PACK
ASPECT SENSOR ASSEMBLY
INERTIA BOOM
UNIVERSITY OF BIRMINGHAM ELECTRONICS PACKAGE
TAPE RECORDER
G.S.F.C. ELECTRONIC PACK
ELECTRON DENSITY BOOM
INTERNATIONAL IONOSPHERE SATELLITE


POLAR ORBITING GEOPHYSICAL SATELLITE
TOPSIDE SOUNDER
ELECTRON DENSITY MEASUREMENTS
BETWEEN 200 AND 600 MILES
S 62-243

RANGER

The first two Ranger flights were designed for spacecraft test and for measurement of interplanetary radiation and fields.

Rangers 3 through 5 included a hard-landing capsule as well as a main bus and were designed to obtain medium resolution TV photos of the lunar surface; to measure gamma ray spectra, to land a seismometer on the lunar surface, and to measure lunar surface radar reflectivity characteristics.

The prime experiment on Rangers 6 through 14 shall be a wide bandwidth television system for obtaining close-up pictures of the moon on approach. An alternate prime experiment for the last two or three flights shall be a high resolution facsimile device which would be landed on the surface in a capsule similar to that used on Rangers 3 through 5 and would furnish a panoramic view of the surrounding area at very high resolutions.

In addition to the prime experiments mentioned above, the following experiments are scheduled for flight on Rangers 7 through 9, subject to the availability of sufficient electrical power to sustain them. Small experiments of this type have not as yet been chosen for Rangers 10 through 14.

1. Measurement of the absolute electron flux in the energy range 250 Kev to a few Mev

   Dr. G. F. Pieper, Applied Physics Laboratory, John Hopkins University

2. Low energy solar proton detector

   Dr. M. Bader, Ames Research Center

3. Study of low energy ions in the interplanetary medium and in the lunar atmosphere

   G. P. Serbu and R. E. Bourdeau
   Goddard Space Flight Center

4. Dust particle experiment for Ranger impactors

   W. M. Alexander
   Goddard Space Flight Center

5. Ionization chamber and counter experiment

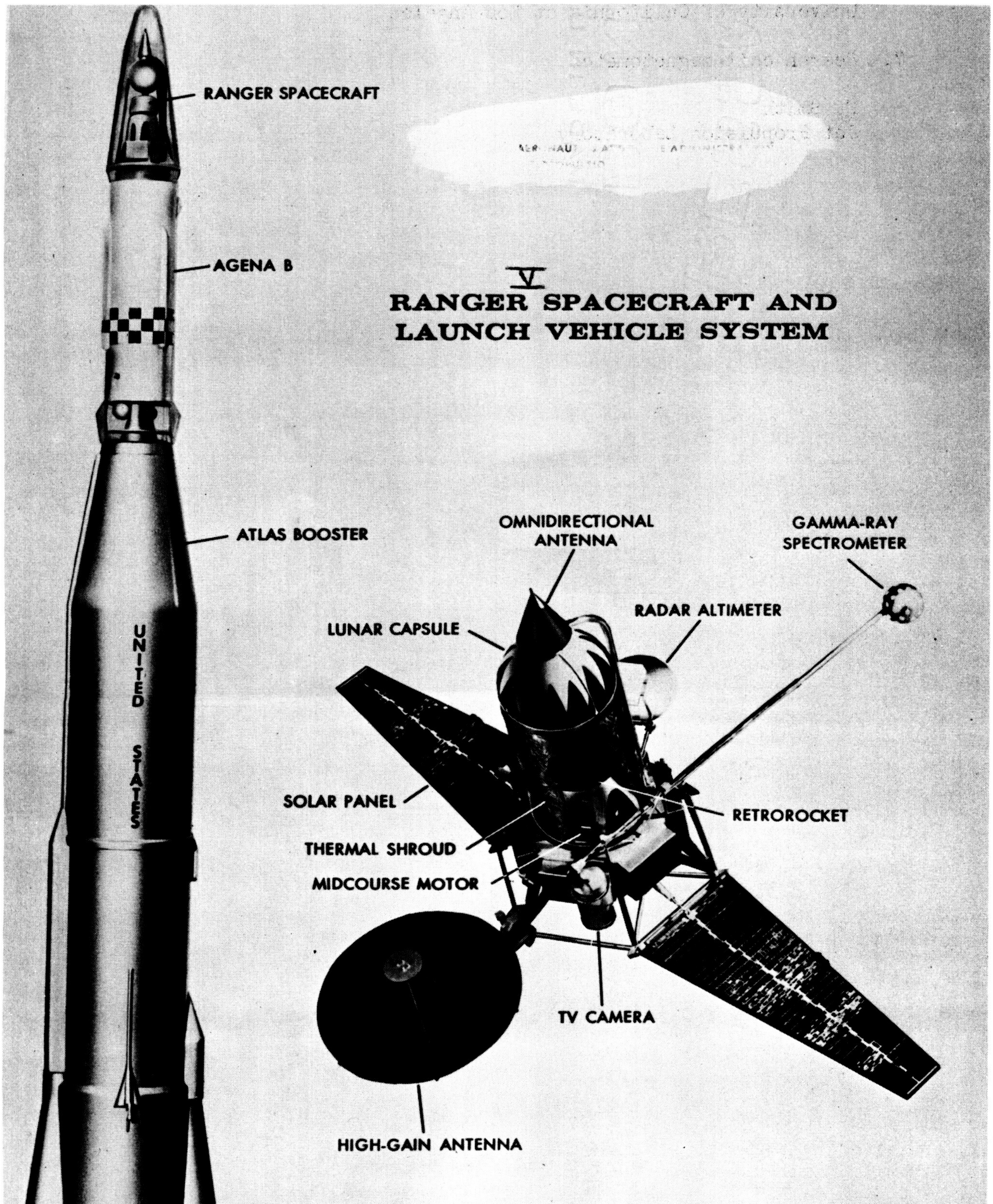
   H. R. Anderson
   Jet Propulsion Laboratory

6. Electron-proton spectrometer

   Dr. T. A. Farley and Dr. N. Sanders
   University of California at Los Angeles

7. Search coil magnetometer

   E. Smith
   Jet Propulsion Laboratory


V
RANGER SPACECRAFT AND
LAUNCH VEHICLE SYSTEM
RANGER SPACECRAFT
AGENA B
ATLAS BOOSTER
UNITED STATES
OMNIDIRECTIONAL ANTENNA
GAMMA-RAY SPECTROMETER
RADAR ALTIMETER
LUNAR CAPSULE
SOLAR PANEL
RETROROCKET
THERMAL SHROUD
MIDCOURSE MOTOR
TV CAMERA
HIGH-GAIN ANTENNA

SURVEYOR

The first major lunar soft lander in the NASA program is the Surveyor. The use of the Surveyor for investigation of the moon is indicated by the following list of experiments selected for the first several missions:

1. Visual surveillance of lunar surface features

   G. P. Kuiper, University of Arizona
   E. M. Shoemaker, U. S. Geological Survey

2. Determine physical properties of lunar surface material

   S. P. Clark, Yale University and Carnegie Institution of Washington, D. C.
   F. Press, California Institute of Technology
   F. E. Ingerson, University of Texas
   G. C. Kennedy, University of California at Los Angeles
   E. M. Shoemaker, U. S. Geological Survey

3. Identify minerals on lunar surface

   H. Hess, Princeton University
   E. Goldberg, University of California at San Diego

4. Determine flux and velocity and mass distribution of material ejected from lunar surface by meteoric impacts

   Experimenters to be designated

*5. Determine body properties of the moon

   M. Ewing, Columbia University
   F. Press, California Institute of Technology

*6. Determine thermal diffusivity and magnetic susceptibility of lunar surface material

   S. P. Clark, Yale University and Carnegie Institution of Washington, D. C.
   F. E. Ingerson, University of Texas
   G. C. Kennedy, University of California at Los Angeles
   E. M. Shoemaker, U. S. Geological Survey

**7. Elemental analysis of lunar surface material

   Experimenter to be designated

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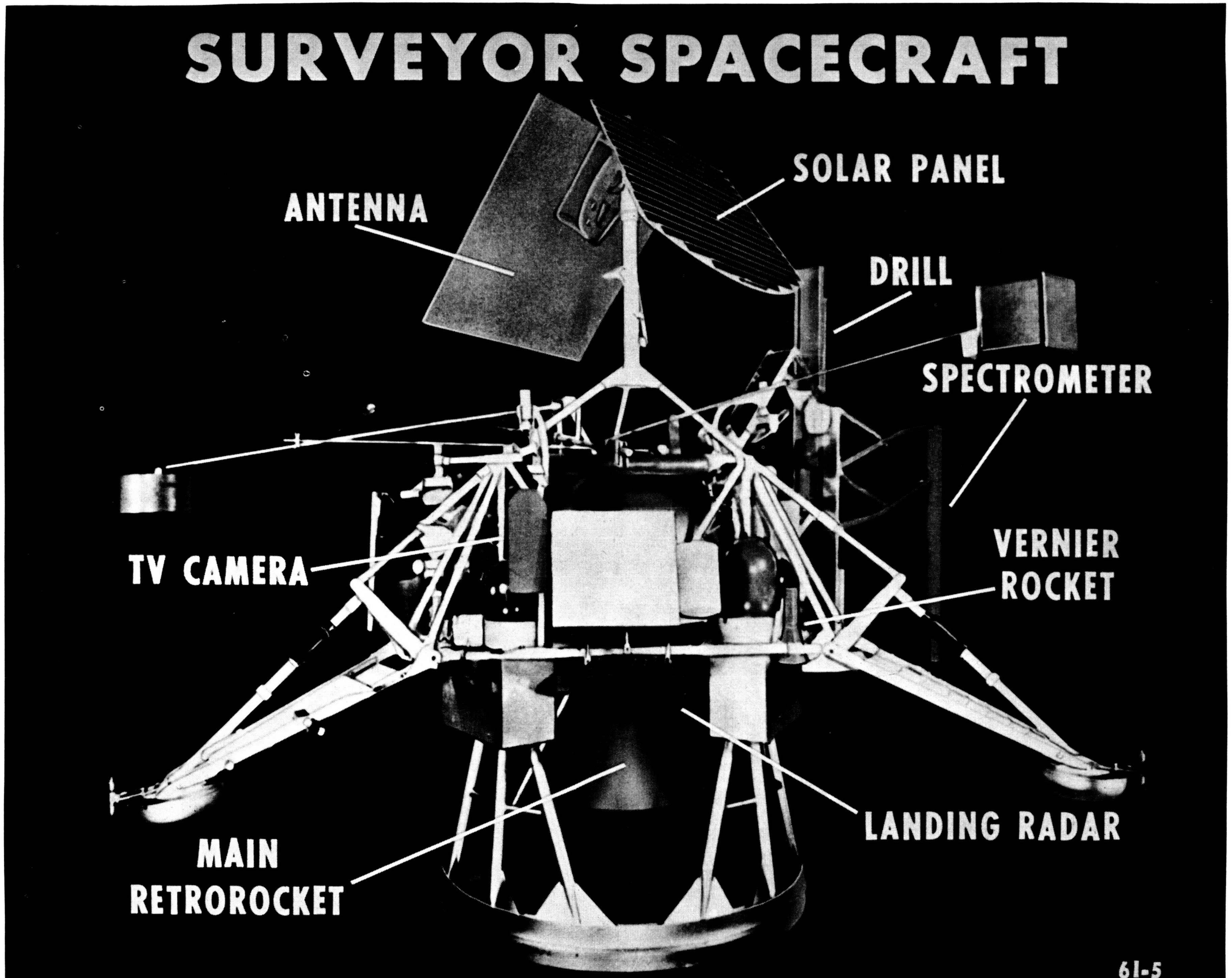
* These experiments are alternates. In event first few mission attempts are successful, they may be replacements for experiments on subsequent missions.

** This experiment being considered for inclusion in first mission attempts.


SURVEYOR SPACECRAFT
ANTENNA
SOLAR PANEL
DRILL
SPECTROMETER
TV CAMERA
VERNIER ROCKET
LANDING RADAR
MAIN RETROROCKET
61-5

MARINER

The Mariner spacecraft is intended to provide exploratory investigations of the planets Venus and Mars.

The first Mariner, called Mariner R, was launched on August 27, 1962. Experiments carried were as follows:

1. Measure Venus surface brightness temperature and temperature at intermediate level in Venus atmosphere:

   A. Barrett, Massachusetts Institute of Technology
   A. E. Lilley, Harvard University
   J. Copeland, Marshall Space Flight Center
   D. E. Jones, Jet Propulsion Laboratory

2. Determine certain constituents and temperature structure of Venus atmosphere:

   L. Kaplan, Jet Propulsion Laboratory
   C. Sagan, University of California at Berkeley
   G. Neugebauer, Jet Propulsion Laboratory

3. Determine spatial and temporal variations of interplanetary magnetic field; measure outer reaches of magnetic field of Venus:

   C. P. Sonett, NASA-Ames Research Center
   P. J. Coleman, Jr., University of California at Los Angeles
   L. Davis, Jr., California Institute of Technology
   E. J. Smith, Jet Propulsion Laboratory

4. Measure total ionization and specific ionization of energy charged particles in interplanetary space:

   H. V. Neher, California Institute of Technology
   H. R. Anderson, Jet Propulsion Laboratory

5. Measure medium energy electrons and protons in space and in vicinity of Mars:

   J. A. Van Allen, State University Iowa

6. Measure flux, energy spectra, and directionality of plasma electrons and protons:

   C. W. Snyder and M. Neugebauer
   Jet Propulsion Laboratory

7. Measure flux, directionality, mass distribution, and velocity distribution of cosmic dust in interplanetary space:

   W. M. Alexander, Goddard Space Flight Center

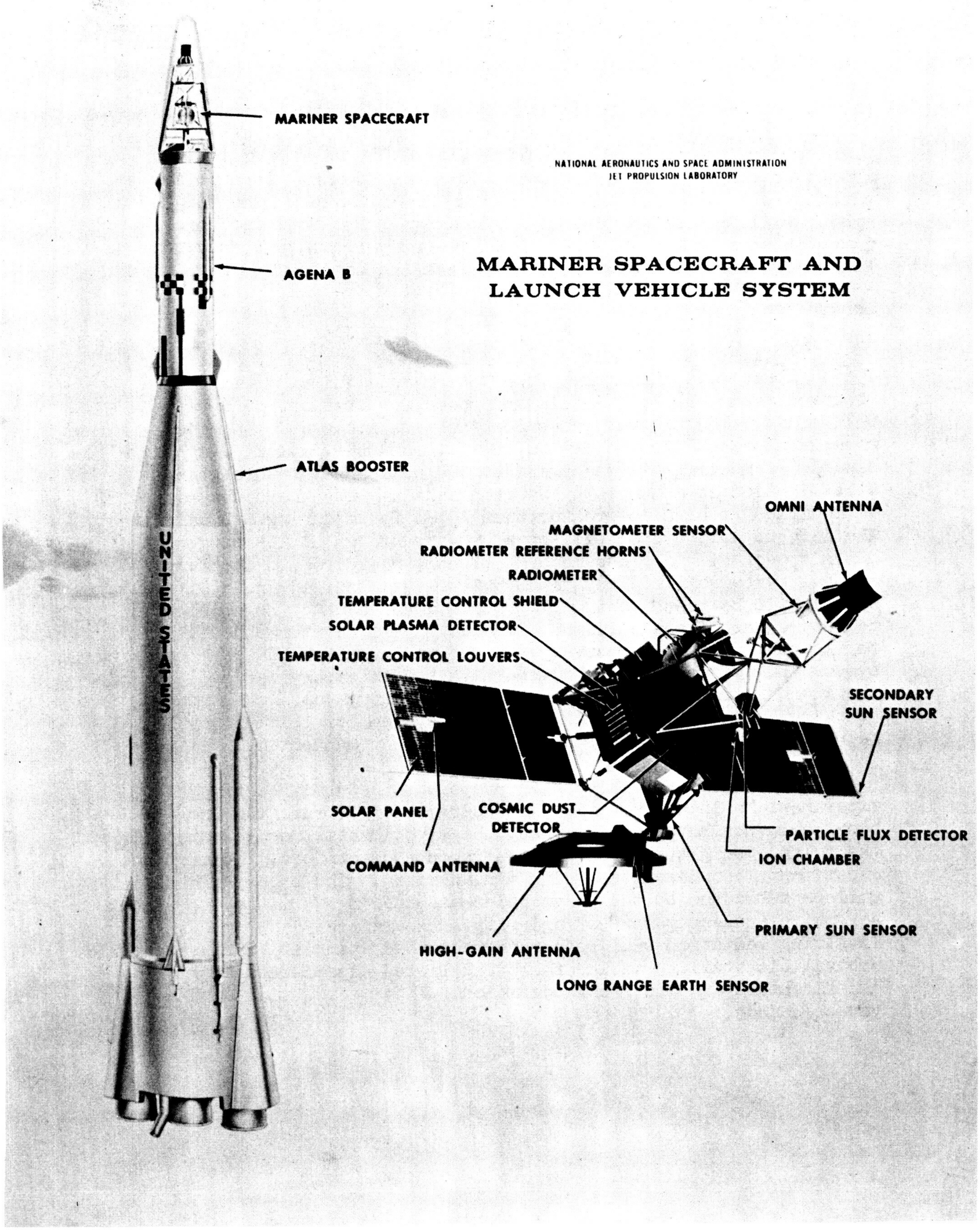
In 1964 Mariner R will again be flown to Venus. Mariner B, which was originally planned for the 1964 Mars mission, is now scheduled to start at the time of the 1965 Venus opportunity. A lighter version, Mariner C, will accomplish the 1964 Mars mission. Experiments for these have not been selected; they will be chosen from a group that includes those for the 1962 Mariner R and a set that was under consideration for Mariner B.

ORBITING BIOLOGICAL OBSERVATORIES

The orbiting biological observatories are a series of biosatellites designed to study the biological effects of outer space environmental factors which cannot be studied on earth. These factors are decreased by zero gravity, high energy and heavy particle cosmic radiation, and complete removal from the effects of the earth's rotation. The spacecraft being designed will support organisms for 14 days and permit recovery. The first three biosatellites are designed primarily to study the effects of decreased or zero gravity, and effects on plant and animal rhythms upon removal from the earth's rotation. The biosatellites will probably be launched from PMR in a polar circular orbit at an altitude of from 150-250 miles. The flight system will include an Atlas D first stage boost vehicle, which is an integral part of the Lockheed re-entry recovery spacecraft. Before re-entry the Agena separates from the capsule which re-enters with a parachute and can be recovered by air or from the water or land.

The first biosatellite will be launched in the last half of 1964. Spacecraft structure, fabrication and equipment will be procured from Lockheed Missile and Space Corporation, Sunnyvale, California. The recovery capsule space available for biological experiments and life support is 125 $ft.^3$ and the payload weight is capable of meeting all requirements and additional future needs. Stabilization is achieved by horizon sensing, and the spacecraft will be modified to have no greater than 10^{-5}G force during orbital flight. The life support system will be a two-gas system of 20% oxygen and 80% nitrogen with a pressure of 14.7 psi. (compared to the Mercury one-gas system of 100% oxygen at 5.5 psi.). This advanced life support system will be tested and will provide advance data for application to future manned space flight. The USAF will have responsibility for launch, tracking, recovery, and communication. The USAF tracking system and telemetry will be used with the telemetry capabilities of the Agena D modified for use with this re-entry capsule. Ground tracking command, and a data receiving system for telemetry will be utilized with both stored and real time communication.

Sixty experiments have been proposed and submitted by experimenters in universities, industry, and government. The bioexperiments have been defined, the experimental designs studied, and the volume, weight, and power requirements determined. Some of the experimental equipment is being miniaturized. The bioexperiments will be submitted to the Space Sciences Steering Committee for final selection and assignment of priority. The fifteen experiments involving radiation will be considered in additional planned eccentric orbital biosatellites. The following listed experiments and experimenters are under consideration. Final selections have not yet been made.


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JET PROPULSION LABORATORY
MARINER SPACECRAFT AND
LAUNCH VEHICLE SYSTEM
MARINER SPACECRAFT
AGENA B
ATLAS BOOSTER
UNITED STATES
OMNI ANTENNA
MAGNETOMETER SENSOR
RADIOMETER REFERENCE HORNS
RADIOMETER
TEMPERATURE CONTROL SHIELD
SOLAR PLASMA DETECTOR
TEMPERATURE CONTROL LOUVERS
SECONDARY
SUN SENSOR
SOLAR PANEL
COSMIC DUST
DETECTOR
COMMAND ANTENNA
PARTICLE FLUX DETECTOR
ION CHAMBER
PRIMARY SUN SENSOR
HIGH-GAIN ANTENNA
LONG RANGE EARTH SENSOR

ORBITING BIOLOGICAL OBSERVATORIES

Experiments and Experimenters

1. Production of microsphere at zero gravity

   S. W. Fox
   Florida State University

2. Sea-Urchin egg experiment

   R. S. Young
   Ames Research Center

3. The rate of observations of certain microbiological processes in conditions of weightlessness

   G. Welch
   University of California

4. Alterations of physical chemical phenomena under conditions of weightlessness

   A. Rescigno
   University of California

5. Mammalian life and respiration in space environment

   C. A. Tobias
   University of California

6. Growth of a plant during an entire life-cycle

   E. A. Ball
   North Carolina State College

7. Growth of a plant tissue culture in a gravity-free state

   E. A. Ball
   North Carolina State College

8. Behavior and performance study

   J. Brady
   WRAIR

9. Brain probe study in primates

   W. R. Adey
   UCLA

10. Squirrel monkey vestibular mechanisms study

    W. Graybiel
    USN, Pensacola, Florida

11. Primate hemodynamics and metabolism in an orbiting satellite

N. Pace
University of California

12. Behavior and reproduction of paramecia in the weightless state

M. L. Ferguson
Goodyear Aircraft Corporation

13. Sub-G effect on photosynthesis and respiration

A. Brown and H. Tsuchyia
University of Minnesota

14. Sub-G effect on cellular phenomena

R. S. Young
Ames Research Center

15. Sub-G effect on plant growth and tropisms

R. S. Young
Ames Research Center

16. Hard vacuum effect on bacterial spores

R. S. Young
Ames Research Center

17. Sub-G and radiation effect on hamsters

L. Musacchia
St. Louis University

18. Cell diffusion

C. A. Tobias
University of California

19. Capillarity, liquid vapor coexistence

C. A. Tobias
University of California

20. Inversion of water beetle egg masses

C. A. Tobias
University of California

21. Inversion of polarity of frog eggs

C. A. Tobias
University of California

22. Effect of radiation and gravity-free environment in space on cell division and growth

H. Krause
University of Maryland

23. Effect of zero gravity and radiation on growth of tissues in vitro

B. Edwards and S. W. Gray
Emory University

24. The effect of weightlessness on growth of the wheat coleptile

B. Edwards and S. W. Gray
Emory University

25. Effects of orbital flight environment on metabolism of daphaia pulex

F. Taub
University of Washington

26. Space flight survival of tilapia mossambica

F. Taub
University of Washington

27. The effects of weightlessness on deoxyribonucleic acid (DNA) phenomena

Spacelabs, Incorporated

28. Collection of airborne spores in near and outer space

R. W. Price
G. E. Company

29. Nutrition and growth in pelomyxa carlinensis during weightlessness

R. W. Price and D. Ekberg
G. E. Company

30. The effect of weightlessness on the rhythmicity of photosynthesis and bioluminescence in dinoflagellates grown in liquid media

R. W. Price and R. Lawton
G. E. Company

31. Effect of zero G on the active transport of ions and/or molecules across active membrane

J. J. Konikoff
G. E. Company

32. Effect of zero G on the metabolism of non-growing culture of motile micro-organisms

J. J. Konikoff
G. E. Company

33. Effect of zero G on the metabolism of actively growing culture of motile micro-organisms

J. J. Konikoff
G. E. Company

34. Effect of zero G on the fertilization and embryonic development of frog eggs

J. J. Konikoff
G. E. Company

35. Perception and selection of gravity

R. Belleville
NASA, Headquarters

36. Body temperature of small mammal (bat in hibernation)

M. Menaker
Harvard University

37. Drosophila - emergence rhythm

A. Pittendrigh
Princeton

38. Endogeny vs. exogeny of biological rhythms in plants (diurnal fluctuation in magnetic fields)

H. Finn
North American

39. Rhythmicity study with mice

F. Halberg
University of Minnesota

40. Evaluation of dosimeters used for physical measurements of space radiation

L. T. Odland
AFSWC, Kirtland AFB

41. Depth dose measurements of ionizing radiation in orbiting tissue equivalent manikin

L. T. Odland
AFSWC, Kirtland AFB

42. Nuclear emulsion experiments on recoverable bioscience capsules

D. E. Guss
Goddard Space Flight Center

43. Low energy electron proton equipment

J. B. Trice
G. E. Company

44. Van Allen and solar flare proton spectrum (distinguish against electrons and obtain spectra and intensity)

J. B. Trice
G. E. Company

45. Biochemistry and biophysical

R. D. Englert
Stanford Research Institute

46. Chromosomal aberration in Chinese hamster and/or experimental primate

M. Bender
Oak Ridge National Laboratory

47. Chromosomal aberrations in human somatic cells

M. Bender
Oak Ridge National Laboratory

48. Comparison of mutagenic effectiveness of equal rad doses of penetrating Van Allen radiation with CO^{60} gamma rays

A. Aparrow and D. Shaver
Brookhaven Laboratory

49. Studies of insect eggs exposed in recoverable satellites that orbit through the Van Allen Radiation Belt

W. N. Sullivan, G. B. Craig and C. N. Smith
University of Notre Dame

50. The somatic or genetic damage or change in silkworm and tick eggs exposed in satellites

W. N. Sullivan
ARS, VSDA

51. Effects of radiation as imposed by biosatellite on tobacco masaic virus

M. Gordon
University of Washington

52. Biological dosimetry of space radiation

T. S. Mobley
AFSWC, Kirtland AFB

53. Use of optimal biological dosimeters in retrievable space vehicles

R. G. Lindberg
Northrop Space Laboratory

54. Radiation effects on a genetically-stable material (barley seeds)

A. Eugster
University of Bern
University of Zurich

55. Mutagenic effectiveness of known doses of gamma irradiation in combination with zero gravity

J. deSerres
Oak Ridge National Laboratory

56. Neurospora back-mutation experiment

A. G. DeBusk
Florida State University

57. Neurospora "balanced lethal" experiment

A. G. DeBusk
Florida State University

58. Neurospora forward-mutation experiment

A. G. DeBusk
Florida State University

59. Back-mutation clone sensing system

A. G. DeBusk
Florida State University

60. Effect of space environment on development and metabolism of tribolium confusum, the flour beetle

J. V. Slater
University of California

UNIVERSITY PROGRAMS

Since its establishment, NASA has supported substantial numbers of basic and applied research projects by grants and contracts. This existing support, called sponsored research, is chiefly project-oriented and related to specific problems such as space flight probes, satellites or deep space experiments. While this research often encompasses fundamental research activities, its project orientation does not attack all the areas of fundamental research which are required to support a rapidly expanding space program. With the Presidential decision to expand and accelerate this effort, it became immediately apparent that sponsored research alone could by no means utilize fully the ability of our universities to help preserve and advance the role of the United States as a world leader in aeronautical and space science and technology.

Accordingly the Sustaining University Program was initiated in January 1962 to increase significantly university participation in space science and engineering and to augment and complement sponsored research activities by:

TRAINING GRANTS - which increase the future supply of scientists and engineers required in space-related science and technology.

FACILITIES GRANTS - which help universities provide facilities urgently needed for space research.

RESEARCH GRANTS - which strengthen universities as a whole and enable them to increase their role in support of NASA's program through encouragement of creative multidisciplinary investigations, development of new capabilities, consolidation of activities, and stabilization of funding.

The training grants will increase the supply of scientists and engineers in space-related science and technology. It has been estimated that by 1970 one-fourth of the nation's trained scientific and engineering manpower will be engaged in space activities. To help meet this demand, we have as a goal the support of about 4000 graduate students per year in 100-150 qualified universities, yielding an annual output of about 1000. With this magnitude of participation, the universities will be in a position to make a significant contribution to the space effort's manpower needs.

Ten universities have been awarded training grants for the support of pre-doctoral graduate students in appropriate areas of space-related science and engineering. Each of the universities will train 10 students during the first year. The grants are renewable each year for a total of three years so long as the students maintain the quality of work satisfactory to the university. The universities selected for initial participation were: Rensselaer Polytechnic Institute, Troy, New York; University of Maryland, College Park, Maryland; Georgia Institute of Technology, Atlanta, Georgia;

University of Michigan, Ann Arbor, Michigan; University of Chicago, Chicago, Illinois; University of Minnesota, Minneapolis, Minnesota; State University of Iowa, Iowa City, Iowa; Texas A. and M. College, College Station, Texas; Rice University, Houston, Texas; and the University of California at Los Angeles. This program is designed to meet the future demands for scientific and technical personnel and is expected to increase considerably in the future in order to keep pace with the rapid expansion of the national space program.

Although the first trainees under this program have just entered school this fall, the response to this program by the universities has been gratifying. The initial program involved 10 trainees at each of 10 universities. Plans are to make grants to a substantially larger number of universities during FY 1963, to permit the entrance of an additional 600 to 750 students in this program during the next academic year.

Five universities have been awarded grants for the construction of research facilities. These grants, first of their kind awarded by NASA, are to provide research facilities to house research activities in space-related science and technology at universities which are making substantial contributions to the national space program. The first of these facilities will begin to become operational in 1964 at the earliest. It is anticipated that it will be necessary to work with a total of some 60-75 universities in this manner. The recipients were the University of Chicago, University of California at Berkeley; Rensselaer Polytechnic Institute, Troy, New York; State University of Iowa, Iowa City, Iowa; and Stanford University, Stanford, California.

Research grants under the Sustaining University Program are issued to enable universities to develop and increase their capabilities to support the growing demands of the national space effort. Such grants are used to support broad multidisciplinary research programs, promote the consolidation of related projects, and encourage new research to fill existing research gaps. Grants are also provided to initiate and encourage the establishment of research programs within currently competent but non-participating groups and institutions. During each of the next few years, several large research programs will be supported, ten to fifteen research grants will be provided to augment existing efforts, and 20 to 30 new universities will receive initial grants.

Total NASA support of activities in the universities has approximately doubled each year since NASA was organized. During Fiscal Year 1962 some $40 million were committed for these activities. Of this $40 million, $2 million were utilized to initiate the training grant program; $6-1/2 million were used to initiate the facilities grant program; and some $3-1/2 million were utilized for the special purpose research grants. The rest of the funds supported project type sponsored research.

During Fiscal Year 1963 the training grant program is expected to increase greatly and $15 million has tentatively been allocated for this purpose; $10 million has been allocated for the support of research facilities; approximately $5 million will be committed to the special purpose research grant activity. Based on past experience, it is anticipated that an additional $40 to $70 million will come out of our program offices for the support of project type research in the universities. Thus it is expected that the university involvement in NASA activities during the current fiscal year will be more than double that of FY 1962. It is extremely difficult to predict the level at which this activity might ultimately stabilize. Obviously, it will not double each year. However, it is probable that it will at least double again following this year's program before the program will stabilize.

SCIENTIFIC AND TECHNICAL ASSISTANCE TO MILITARY PROGRAMS

NASA's scientific activities afford considerable help to military programs in missile and space operations, in that NASA collects data which the Department of Defense would otherwise have to acquire itself. This information is freely available to the Department of Defense.

Explorers XIV and XV - Subsequent to the discovery that the July 9 atomic blast had created a new artificial radiation belt at altitudes lower than the natural belts, NASA launched these two satellites to study the new radiation belts. The flights served two purposes - to study the belts, and to obtain their relationships to the original blast as a scientific phenomenon. The information gained will show the effects of nuclear explosions on the radiation belts, and possibly will aid in guiding future studies in the military problems of the creation of artificial radiation belts for defensive purposes and in throwing light on the environment of military missiles and spacecraft in the wake of a nuclear explosion. Both Explorers XIV and XV carried experiments to assess the damage to solar cells in the space environment.

NASA launched the Canadian satellite, Alouette, which is making a careful study of the ionosphere from above. All information regarding the ionosphere will be of assistance to military communications programs based on radio and radar.

NASA made water releases in the upper atmosphere from sounding rockets and from test flights of the Saturn launch vehicle. The information will be pertinent to military programs which might involve the release of foreign matter into the upper atmosphere.

The sounding rocket program continued to explore the details of the ionosphere. All results will be directly applicable to communications in radio and radar.

The information gained from the Orbiting Solar Observatory, OSO I, with respect to solar flares and their relationship to the solar winds and to the energetic solar protons ejected during a flare will be of direct use to an organization that launches spacecraft either manned or unmanned and to communications. Experiments of direct utility to spacecraft carried on OSO I included an experiment for the detection of dust particles and an experiment for studying the behavior in the space environment of temperature control surfaces to be used on satellites. Information of the type gathered by OSO I will be used to try to predict the occurrence of solar flares.

ASSISTANCE TO OTHER PROGRAMS

The NASA space science program is providing information which is beneficial to other programs. Perhaps the most immediate returns will be in the area of manned space flight. The lunar program results will be extremely important to the Office of Manned Space Flight. The data on cislunar and lunar environment, lunar constants, surface, mapping, and reconnaissance all help to determine the design of Apollo vehicle shielding, landing gear, landing sites selection, and will be factors in other areas of final system design. By providing data on the environment in space, the Geophysics and Astronomy Programs will contribute to the design of the Apollo spacecraft. The understanding of solar flare phenomena will help decrease the radiation hazard to Apollo. Information on the radiation environment will be used by the Office of Applications to design communication satellites. The data gathered on the ionosphere will provide valuable information for conventional communication systems.

Other data gathered on the environment of near-earth space will be useful to and aid in the development of meteorological satellites. Results in the bioscience area will assist in the immense task of putting man into space adequately protected from the peculiar hazards in space, and adequately sustained by a suitable environment.

SATELLITE APPLICATIONS

Communications Satellites

A. Passive satellites

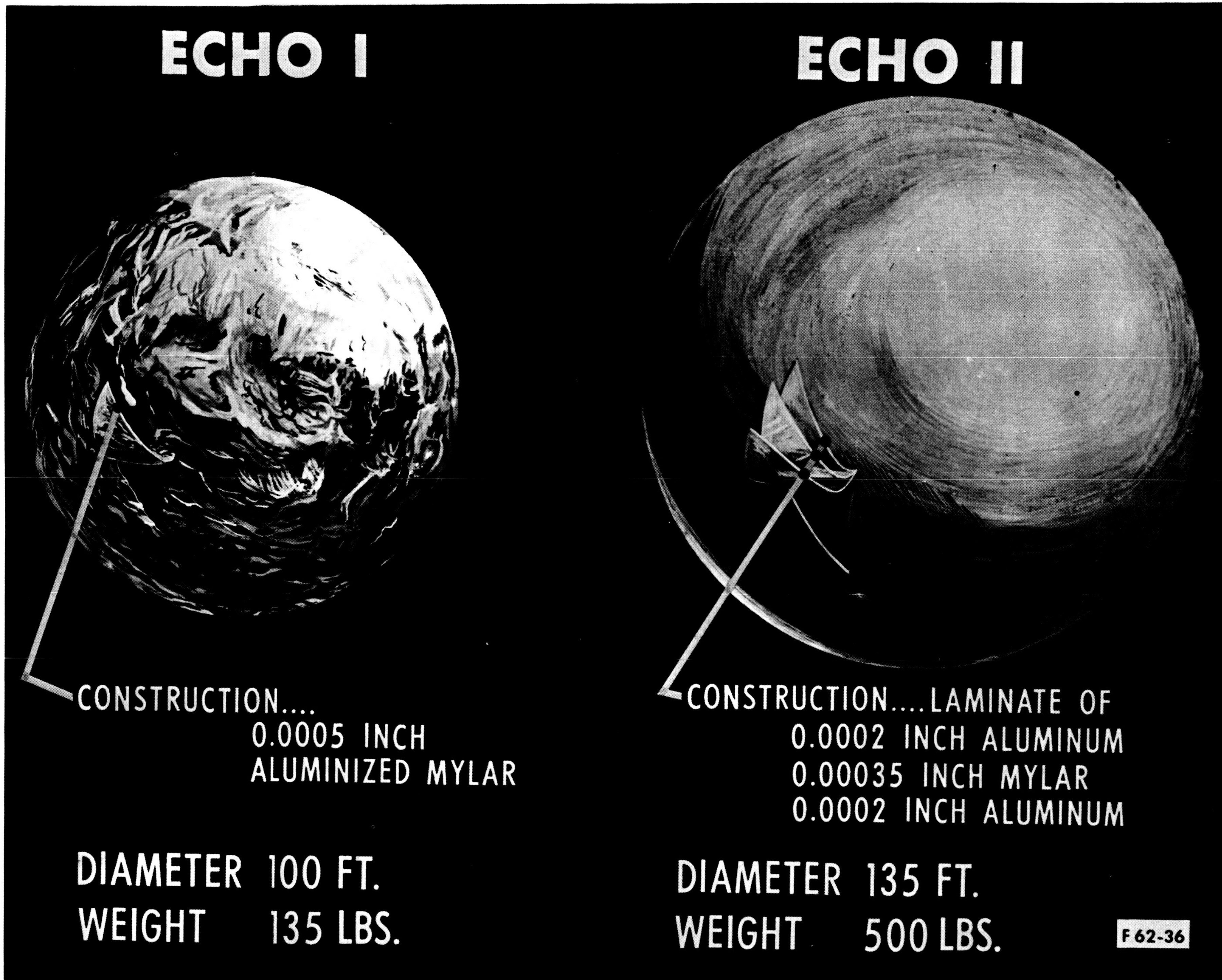
1. General. ECHO I experience and the fact that the satellite is still in orbit rendering useful data, although it is now distorted in shape, has dictated a continuation of the passive satellite program. The next phase is already under way. The first step calls for the development and flight test of a larger, rigid spherical satellite which will exhibit long life. Because rather large numbers of satellites are required for operational systems, economic considerations make it necessary that more than a single satellite be placed into orbit with a single launch vehicle. The second step, therefore, calls for the development and flight test of a multiple satellite launching from a single spacecraft.

2. Rigidized sphere. The sphere, 135 feet in diameter, will weigh approximately 500 pounds, and will be constructed of a laminate of two layers of aluminum foil 0.0002 of an inch thick on either side of a 0.00035 of an inch thick sheet of Mylar. This construction will provide a resistance to buckling of a factor of 20 more than the ECHO I construction. The sphere will be inflated by sublimating materials to a pressure which will stress the skin just beyond the yield point of the aluminum. When this is done, all "memory" of the sphere's previously folded condition will be erased, and it should not wrinkle even after the inflating gas has escaped. This rigidized sphere represents a significant step toward providing a long-lived, erectable, space structure.

This sphere will be launched from PMR into a highly inclined, circular orbit of 650 n.m. altitude in the 1st quarter of 1963 by a Thor-Agena B vehicle. During the course of development two ballistic firings with Thor vehicles were made at AMR to test the ejection and inflation mechanisms. On the first the balloon burst on inflation. The second was successfully, though not completely, inflated in flight.

3. Advanced Passive Satellite Development.

Investigations are underway directed towards the development of reflective space structures which provide more gain than spheres. Some of the structures currently under consideration include a woven wire mesh with a photolyzable material and a wire mesh that is expanded into a desired shape by a method other than pressure inflation. The investigations also include studies aimed towards the development of improved and lighter materials for spheres. Two such possibilities now being looked into are the so-called etched sphere and the expanded mesh sphere. Development of single spacecraft capable of injecting multiple passive satellites into orbit is under study.


ECHO I
ECHO II
CONSTRUCTION....
0.0005 INCH
ALUMINIZED MYLAR
DIAMETER 100 FT.
WEIGHT 135 LBS.
CONSTRUCTION....LAMINATE OF
0.0002 INCH ALUMINUM
0.00035 INCH MYLAR
0.0002 INCH ALUMINUM
DIAMETER 135 FT.
WEIGHT 500 LBS.
F 62-36

B. Active satellites

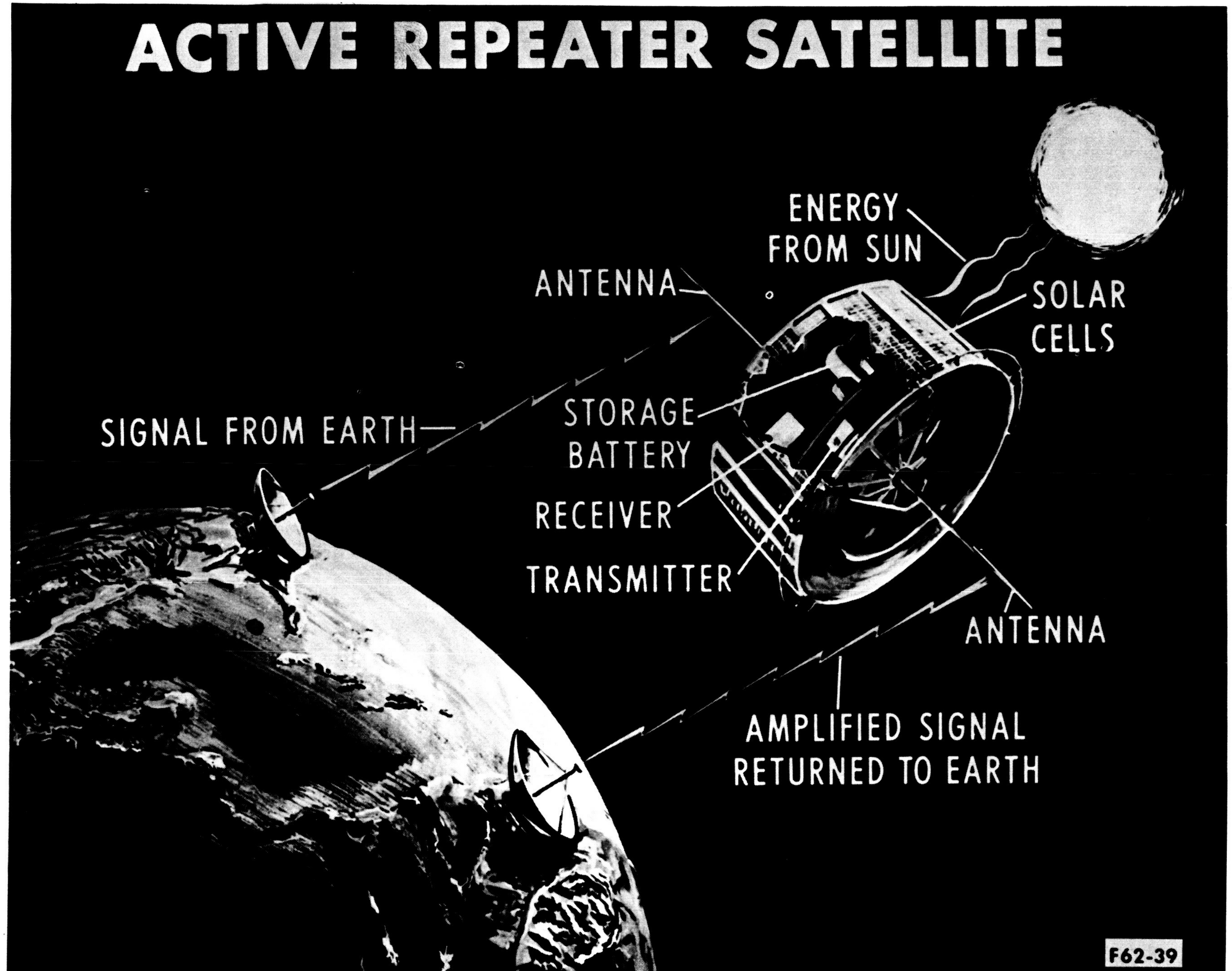
1. Project Relay. NASA is developing a low-altitude active satellite capable of transmitting television signals across large distances. The spacecraft, being built by RCA under NASA contract, will weigh about 170 pounds, and will contain two complete communications transponders, and a solar cell life test plus an environmental radiation measurement system.

The power supply will consist of solar cells and a storage battery. Solid state (i.e., transistors and diodes) components are being used throughout for the electronics of the system, except for the final output stage of the communications transmitters. This must necessarily be a vacuum tube today because there are no transistors capable of the power (10 watts) in the required frequency range. A traveling wave tube (TWT) is being developed by RCA for this purpose. Tubes of this type show promise toward supplying the long life and wide band characteristics required for this application. With an omnidirectional antenna on the satellite and 85-ft. aperture antennas and parametric amplifiers on the ground, this satellite should be capable of relaying radio signals of television bandwidth between stations each 5,000 miles from the satellite. Transmission will be from ground to satellite at 1725 Mc/s and from satellite to ground at 4170 Mc/s.

Of most concern to the development of low altitude active satellites is the life of the satellite, and therefore the effect of the space environment on the components of the satellite system. It is known that the radiation existent in the Van Allen belts and in other regions of space with solar disturbances can affect the life of solid state components. It is possible to shield against some of this radiation but not against others. It is, therefore, important that a radiation experiment be carried out in conjunction with Project Relay to: Measure the effect of this radiation on various components of the communications system; measure the effects of this radiation on selected types of advanced solar cells with different levels of shielding, and to measure the effects of this radiation experienced by the satellite during its life. Both the electron and proton densities must be measured to fully understand the effect of each type of particle.

Ground Stations for Project Relay will be the 3,600 sq. ft. aperture horn antenna of AT&T at Andover, Maine, and the 40 ft. diameter paraboloid of ITT at Nutley, New Jersey. The former will be used for 2-way wide band communications with stations being provided by Britain and France. The latter will be used for 2-way narrow band transmission between Britain, France, and Brazil. West Germany and Italy will provide stations capable of receiving in the narrow band. West Germany's station will also be able to receive in the wide band.

The first Relay satellite is scheduled for launch from AMR by a Thor-Delta vehicle in the fourth quarter of 1962. The orbit intended is elliptical, with an apogee height of 4500 n.m. and perigee height of 700 n.m.


ACTIVE REPEATER SATELLITE
ENERGY FROM SUN
SOLAR CELLS
ANTENNA
STORAGE BATTERY
RECEIVER
TRANSMITTER
ANTENNA
SIGNAL FROM EARTH
AMPLIFIED SIGNAL RETURNED TO EARTH
F62-39

2. Project Telstar (AT&T)

As part of the effort to accelerate the development of communications satellite systems, NASA has entered into a cooperative agreement with and launched for the American Telephone & Telegraph Company, TELSTAR, an experimental satellite designed by the Bell Telephone Laboratories.

The objective of Project Telstar is to investigate in orbital flight the technological and operational problems of transmission of wide band communications by means of an active artificial earth satellite. The test consists of placing a satellite into orbit and communicating via the satellite. Transmission from the ground to the satellite is at 6390 Mc/s and from the satellite to the ground at 4170 Mc/s.

The project includes one launch in calendar year 1962. Plans for a second launch in the second quarter of 1963 are now under study.

The prime objective of the first experiment is to measure all transmission characteristics under conditions of orbital operation and to check the performance of facilities newly developed for acquisition, satellite tracking, and ground antenna pointing under actual operating conditions.

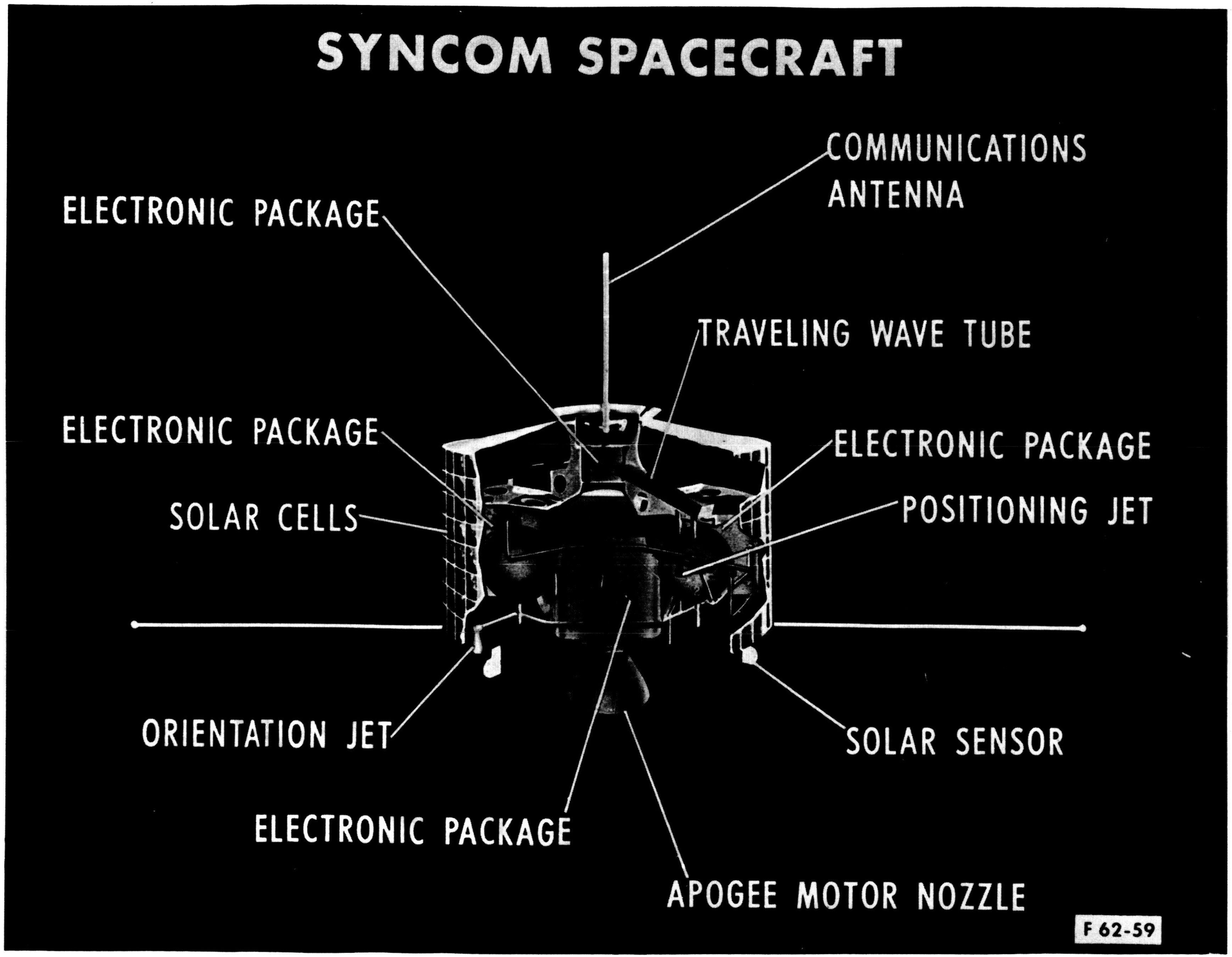
A second objective is to gather information about the space environment with particular attention to conditions affecting performance over long periods of time. For this purpose the spacecraft carries equipment to measure particle radiation flux and the cumulative effect of radiation damage to semiconductor devices, as well as sensors for measuring temperature and component performance.

The project is being carried out jointly by NASA and Bell Telephone Laboratories, Incorporated (BTL) with NASA responsible for providing the launch vehicle and arranging for the launching of the spacecraft, and with BTL responsible for providing the spacecraft and ground station facilities and carrying out the post-launch experiments. BTL pays the cost for its own activities and reimburses the United States Government for expenses incurred.

The NASA Goddard Space Flight Center provided Delta vehicle management and launch support and, in addition, provided Minitrack tracking and telemetry information for a period of two months after launch.

3. Project Syncom.

Realizing that the 24-hour stationary satellite of full capability is still several years away, and that experience at these altitudes is desirable, NASA is planning to test a light-weight, limited-capability communications satellite with attitude stabilization and period control, capable of being launched into a 24-hour inclined orbit with the Thor-Delta launch vehicle and an additional spacecraft propulsion unit. The spacecraft with propulsion rocket will weigh approximately 145 pounds. The active repeater will be capable of relaying a few telephone conversations or several teletype messages.


SYNCOM SPACECRAFT
COMMUNICATIONS ANTENNA
ELECTRONIC PACKAGE
TRAVELING WAVE TUBE
ELECTRONIC PACKAGE
ELECTRONIC PACKAGE
SOLAR CELLS
POSITIONING JET
ORIENTATION JET
SOLAR SENSOR
ELECTRONIC PACKAGE
APOGEE MOTOR NOZZLE
F 62-59

The Hughes Aircraft Company has been awarded the contract for developing the spacecraft and associated ground command and control equipment. The Department of Defense will man ground stations (60 ft. dishes at Fort Dix, N.J., and Camp Roberts, California) and in addition, will provide two transportable ground stations and a ship with 30 ft. antennas. Frequencies will be 8000 Mc/s ground-to-satellite and 2000 Mc/s satellite-to-ground. Ground transmitter power will be 20 kw, and 2 watts will be radiated from the satellite.

The first launch is scheduled for the 1st quarter 1963 from AMR.

Meteorological Satellites

A. Tiros

The six consecutive successful launches of the Tiros series (I, launched April 1, 1960; II, launched November 23, 1960; III, launched July 12, 1961; IV, launched February 18, 1962; V, launched June 19, 1962; VI, launched September 18, 1962) have demonstrated that meteorological satellites could be developed around such sensors as TV cameras and radiation detectors and transmit meteorologically useful data to the ground with satisfactory fidelity.

In all, the six Tiros satellites, as of November 7, 1962, have transmitted 185,124 TV pictures (of which over 70% were of meteorological significance) from which approximately 3000 nephanalyses have been prepared. In addition many satellite storm advisories have been issued and storm systems have been tracked. For example, during the month of September 1962 Tiros photographed tropical storms Becky, Celia, and Claudia, Typhoon Amy, and Hurricane Alma.

Tiros IV, as the previous three satellites, included TV cameras and infra-red detectors in its experimental equipment. It was launched in a 48 degree inclined orbit and provided effective ice reconnaissance data. In addition, Tiros IV provided last minute observations in support of Mercury, Ranger, and Antarctic Resupply, and Joint Task Force 8.

The launches of Tiros V and VI were timed so as to provide the maximum coverage in the northern hemisphere during the hurricane season. Both were launched in an orbit inclined 58 degrees to the equator and both were launched without the IR sensors.

The accomplishments of Tiros have been many, however, only a few will be mentioned here. Tiros has demonstrated the ability to identify and track sea ice by use of satellite data; Tiros has shown the potential for using infra-red data for nighttime cloud observations; Tiros has demonstrated that the organization of cloud patterns is far greater than anticipated, particularly the spiral banding observed in storms; Tiros noted a previously unknown convective pattern which is now frequently observed over ocean areas.

Additional Tiros satellites are scheduled to be launched during the first and second quarters of 1963.


TIROS
RECEIVING ANTENNA
SOLAR CELLS
WIDE ANGLE RADIOMETER
MAGNETIC ORIENTATION COIL
INFRARED ELECTRONICS
TAPE RECORDER
TV CAMERA
TRANSMITTING ANTENNA
F 62-6

B. Nimbus

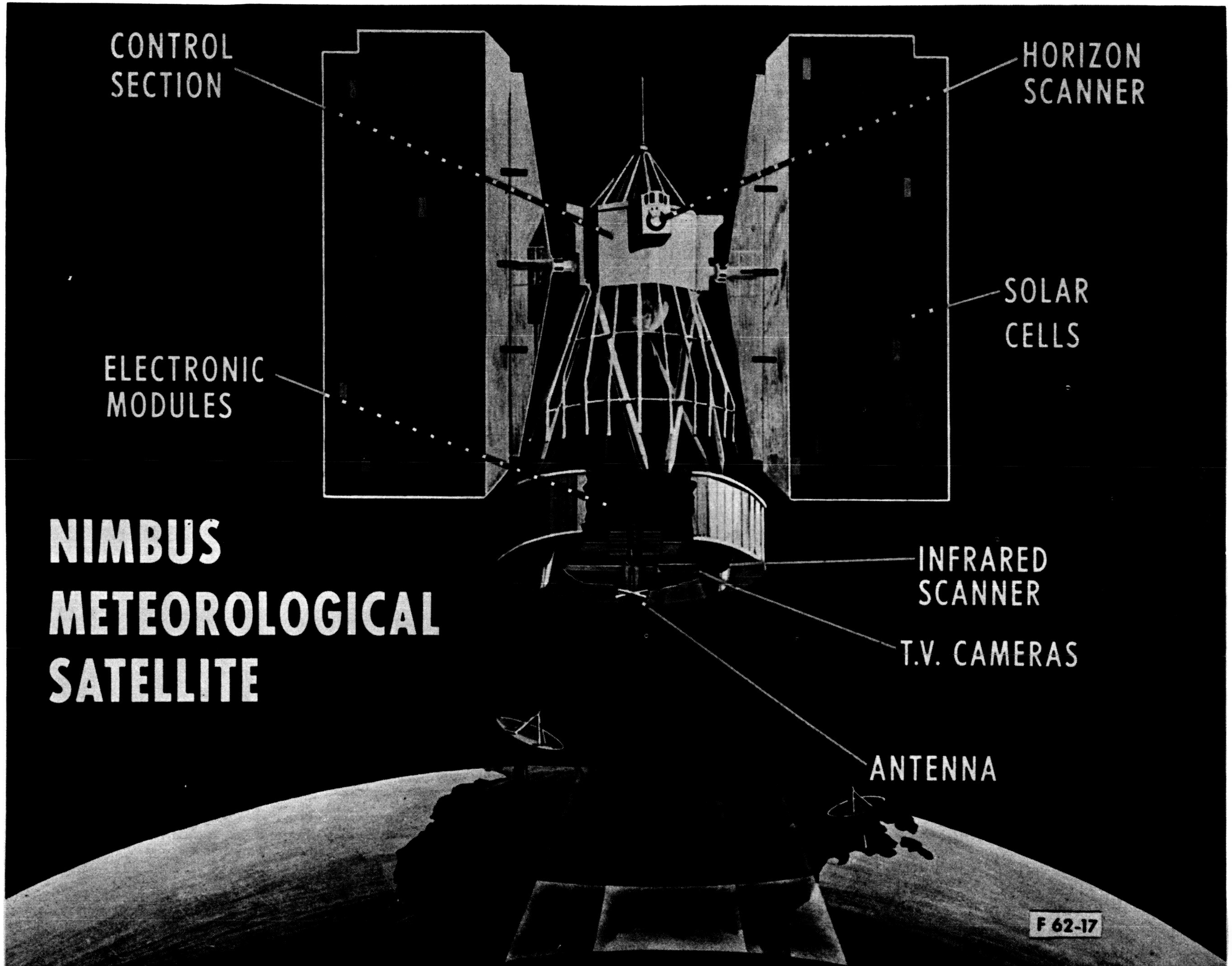
Nimbus, the more advanced successor to Tiros, will be a series of meteorological satellites with many common components (data storage, controls, orientation, stabilization, power supply, structure, etc.) and a flexible capability for improving old and introducing new sensory systems, as required.

The first Nimbus is scheduled to be launched in the third quarter of 1963, with subsequent launches at intervals of six months to a year. Being earth-stabilized, its cameras and other atmospheric sensors will always face the earth. Moreover, its quasi-polar (80° retrograde) orbit will cause it to view each area of the earth twice a day, at about twelve-hour intervals initially near noon and midnight.

The first Nimbus is expected to weigh about 700 pounds and be a 500 nautical mile circular orbit. Sensors will include improved vidicon cameras of increased coverage and resolution, and a better radiation sensory package. Later Nimbus spacecraft are expected to be of greater weight, to be placed in higher altitude orbits, and to carry new types of sensors such as image-orthicon cameras to obtain night cloud cover, a radiation spectrometer, electrostatic tape cameras, sferics sensors, and possibly radar.

Under present plans, the first R&D Nimbus will also serve as the first spacecraft under the National Operational Meteorological Satellite System with its data being sent, in real time, from the data acquisition station now being completed in Fairbanks, Alaska, to the National Meteorological Center. There they will be analyzed and the resulting weather information distributed to civilian (domestic and foreign) and military weather services and stations. Later Nimbus spacecraft will serve similar dual roles; interleaved with them will be truly operational meteorological satellites based on the results of the Nimbus R&D program which, from its earliest conception, has been planned to serve as the basis for the first operational meteorological satellite system.

Nimbus was designed by personnel of NASA's Goddard Space Flight Center. On the basis of technical specifications prepared by this Center, the many subsystems and the integration and environmental testing of the spacecraft as a whole have been contracted out to industry. General Electric (MSVD) holds the integration and test contract and the controls subsystem contract; RCA (AEP) the power subsystem and the TV camera subsystem contracts. At the present stage of development, major subsystems are undergoing prototype flight testing. Spacecraft prototype and flight model testing are scheduled for late in 1962 and during 1963 with first launch scheduled in the later half of that year.


CONTROL SECTION
HORIZON SCANNER
SOLAR CELLS
ELECTRONIC MODULES
NIMBUS METEOROLOGICAL SATELLITE
INFRARED SCANNER
T.V. CAMERAS
ANTENNA
F 62-17

SUMMARY OF NASA LAUNCH VEHICLES

Introduction

The following summarizes the capabilities of NASA launching vehicles for space research and exploration. The vehicles fall into two general categories.

1. Sounding rockets
2. Satellite and space probe vehicles

The sounding rockets are relatively inexpensive and simple to operate, but are limited to small payloads and vertical or near-vertical flights. The satellite and space probe vehicles are ranged from the Scout all-solid launch vehicle to very large vehicles capable of launching man-carrying spacecraft on missions to the lunar surface and return.

Sounding Rockets

Description: A family of seven sounding rockets is used in the geophysical sounding program. These are relatively simple rockets that can be launched at precise times from several sites. About 60 are being launched each year from Wallops Island, Fort Churchill, and Australia.

The types of programs in which these rockets are being used show a strong dependency of objectives or requirements of subsequent firings on the findings of the initial firings in a given family of observations. Consequently, specific long-range firing schedules are not practical for sounding rockets. Based on projected research program planning, a sufficient number of each rocket type is ordered to satisfy the various program needs foreseen.

Typical sounding rockets now utilized are listed in the following table with their nominal costs and capabilities:

Vehicle	Cost (Thousands of Dollars)	Capability: Altitude (miles)	Capability: Payload Wt. (pounds)
Aerobee 100	20	65	70
Nike-Apache	10	150	50
Aerobee 150,150A	30	150	150
Aerobee 300	38	230	50
Argo D-4	50	800	50
Argo D-8	140	1150	130
Nike-Cajun	10	100	50

The Scout is used as a sounding rocket as well as a satellite booster. Its description and capabilities are included in the section on Satellite and Space Probe Vehicles.

Satellite and Space Probe Vehicles

The objectives of the Unmanned Launch Vehicle Program are to provide vehicles with the capability to perform reliably and economically the unmanned orbital, lunar, planetary, and interplanetary missions. Satellite and space probe vehicles currently available in the program are Scout, Delta, Thor-Agena, Atlas-Agena, Atlas-Centaur, and Saturn.

The plan for Launch Vehicles to meet unmanned satellite and space probe mission requirements considers the following:

Mission	Spacecraft Weight Range
Orbital	150 to 20,000 lbs.
Lunar	750 to 9,000
Planetary	400 to 15,000

Weight ranges when considered from a Launch Vehicle point of view can be categorized into three groups: Small, medium, and large. The range of payload capability by vehicle class is:

Mission	Small	Medium	Large
	Scout, Delta	Thor-Agena Atlas-Agena Atlas-Centaur	Saturn C-1B (2 & 3 stages) & Saturn C-5
Earth Orbital	150-700 lbs.	5,000 to 10,000 lbs.	$>$ 20,000 lbs.
Escape	50 lbs.	750 to 2,500 lbs.	$>$ 8,000 lbs.
Planetary	0	400 to 1,500 lbs.	$>$ 4,000 lbs.

A description of each launch vehicle, along with its capabilities is provided in the following paragraphs:

SCOUT

Description: Scout is the smallest of the launch vehicle family. All of its four stages use solid rockets. Because of its relative simplicity, the Scout can be launched from relatively inexpensive installations. It is a low-cost vehicle which can be used for a large variety of scientific payloads such as high velocity probes, reentry models and satellites. Its guidance and control system incorporates a digital programer and 3-axis stabilization for all except the spin-stabilized fourth stage. Chance-Vought, Dallas, Texas, is the vehicle prime contractor and is responsible for all vehicle items except the motors. The motors are obtained from Aerojet, Sacramento, California; Thiokol, Huntsville, Alabama; and the Allegany Ballistics Laboratory, Cumberland, Maryland.

Mission Capability: The present Scout is capable of placing 220 pounds in a 300 n.m. easterly orbit. By next year this capability will be increased to 250 pounds.

Schedule: Starting with the first flight on July 1, 1960, eight developmental and five operational vehicles have been flown to date. The success rate resulting has been slightly over 50%. A well integrated Scout program has been established between NASA and DOD. Thirty vehicles are being procured through CY 1963 to fulfill present NASA and DOD requirements. In addition, a fully integrated logistic support system for the two Scout launch sites (Wallops Island PMR) has been established by NASA with joint funding.

DELTA

Description: The Delta is a three-stage vehicle, in which the first stage consists of a production Thor with the nose cone and guidance removed. The second stage is a modified version of the Vanguard second stage. A radio guidance system (BTL) is installed in the second stage to provide velocity and attitude control. This includes coast-phase attitude control which affords much higher orbits with Delta than with previous vehicles since a prescribed vehicle attitude can be maintained up to 2000 seconds after second-stage burnout. An NPP X-248 solid propellant rocket motor is used as the Delta third stage. Prior to ignition, this stage is spun up to 150 rpm to obtain spin stability after separation, since neither guidance nor autopilot is carried in the third stage.

Mission Capability: The Delta is capable of launching a 100-pound space probe or putting an 800-pound payload into a 300 n.m. circular orbit.

Schedule: The first Delta flight was scheduled for 1960 with flights extending to 1962. After a second stage coastphase failure during the first launching in March 1960, Delta has had 13 consecutive fully successful launchings, placing each payload in an orbit very close to that planned.

An additional fourteen vehicles have been ordered for use with Tiros, active communication satellite programs, and additional scientific satellites. These launches will continue well into calendar year 1963, and perhaps beyond, at a rate of one to two per month.

THOR-AGENA-B

Description: The Thor-Agena-B is a two-stage vehicle in which the first stage consists of a production Thor with the nose cone and guidance unit removed. First stage propellants are liquid oxygen and RP-1 fuel. The second stage consists of an Agena-B vehicle*. The Thor-Agena-B is an improved version of the vehicle used by the Air Force in the Discoverer series.

* Unsymmetrical dimethyl hydrazine (UDMH) and inhibited red fuming nitric acid (IRFNA) are the Agena B propellants.

Mission Capability: The objective of the Thor-Agena-B is to gain increased payload weight and orbit altitude at an early date and at minimum cost. This vehicle will be capable of launching a payload of over 1500 pounds into a 300 n.m. circular orbit, or a 650 pound Nimbus into a 600 n.m. circular polar orbit.

Schedule: Ten Thor-Agena-B vehicles are currently planned through 1964, including the Nimbus meteorological satellite. All current Thor-Agena-B launches are for scientific and applications satellites which require polar orbits, hence they will be launched from PMR.

ATLAS-AGENA-B

Description: Atlas-Agena-B is a two-stage vehicle. The first stage is a D model Atlas modified to accept a second stage. The Agena-B second stage is the stage described for the Thor-Agena-B. The Atlas-Agena-B was developed by the Air Force and will be extensively used in Air Force programs from the Pacific Missile Range.

Mission Capability: The Atlas-Agena-B is being employed to launch the Ranger series of hard lunar landing missions and the Mariner Planetary Probes and provide increased payload and orbit altitude capability for several earth satellite missions. It can place about 5000 pounds into a 300 n.m. circular orbit, send over 700 pounds to the moon (Ranger), or inject 450 pounds to Venus (Mariner).

Schedule: The first NASA Atlas-Agena-B was launched on August 23, 1961. This flight, the initial Ranger launching, achieved only a partial success in that it failed to obtain a second burn of the Agena stage, which prevented its escape from the prescribed 100 n.m. parking orbit. Eighteen Atlas-Agena launchings are programed through 1964. Long range planning currently reflects a sustained rate of firing through 1965 and 1966 with a taper-off in 1967.

CENTAUR

Description: Centaur is a 10 ft. diameter high-energy upper stage powered by two Pratt & Whitney RL 10-A-3 liquid hydrogen-liquid oxygen engines of 15,000 lb. thrust each. The development launches of Centaur will use a modified Atlas-D as a first stage. This configuration is over 105 feet long and weighs about 300,000 lbs. at launch. Operational vehicles will use more powerful Atlas boosters.

Mission Capability: The high energy propellants used in Centaur give it a payload capability substantially above that of the Atlas-Agena-B. Atlas-Centaur can place a payload of over 9,000 pounds in a low earth orbit. Its performance advantages for high velocity missions is even more marked. It will be used by NASA principally for the Surveyor series of unmanned soft lunar landings and the Mariner planetary shots.

Schedule: The first development flight of Centaur took place on May 8, 1961. The vehicle failed during first stage flight, probably due to aerodynamic forces. The development test program extends through 1964, with the first Surveyor payload scheduled for late in 1964. Centaur, as an upper stage for Atlas and possibly Titan II or Saturn C-1, is expected to remain operational throughout this decade.

SATURN C-1

Description: The Saturn C-1 is a multi-purpose space booster vehicle of approximately 1.5 million pounds of initial thrust. The first stage, approximately 80 ft. long, 257 inches diameter, weighing 103,000 #dry is powered by eight Rocketdyne H-1 engines of 188,000 pounds thrust each. The four inner engines are fixed and the four outer engines are gimballed for pitch, yaw, and roll control. Of the nine propellant tanks, the center tank and four of the outer tanks contain liquid oxygen and the remaining four hold the hydrocarbon fuel.

The Saturn S-IV, approximately 41 ft. long, 220 inches diameter, weighing 11,978 #dry, is powered by six Pratt & Whitney RL10-A-3 engines of approximately 15,000 pounds thrust each (Centaur engines) and will burn approximately 100,000 pounds of liquid oxygen and liquid hydrogen.

A potential third stage for the Saturn could be a slightly modified Centaur stage, which also uses liquid oxygen and liquid hydrogen. Such a three stage vehicle is estimated to be 188 feet high.

Mission Capability: The vehicle can be used for both manned and unmanned orbital missions, such as Dyna-Soar, Apollo space crew training, etc., with a payload capability of about 20,000 pounds in a 300 n.m. orbit. With addition of a suitable third stage, payloads of about 3,500 pounds could be put in a 24-hour equatorial orbit; and lunar and deep space-missions performed with an escape payload of about 6,000 pounds.

SATURN C-1B

Description: The C-1B is a two-stage launch vehicle. The first stage (S-1) to be powered by a cluster of H-1 engines developing a total sea level thrust of approximately 1,500,000 pounds. The second stage (S-IVB) to be powered by a single J-2 engine developing a total vacuum thrust of approximately 200,000 pounds. The first stage will be a slightly modified version of the current S-1 stage being developed by MSFC. The second stage will be a slight modification to the S-IVB stage currently being developed by Douglas for use on the Advanced Saturn C-5 based on design concepts from MSFC.

Mission Capability: Primary Mission. The primary mission of the C-1B launch vehicle two-stage configuration shall be to place an Apollo spacecraft, weighing approximately 32,500 pounds, without lunar mission propellants, into an earth orbit of approximately 105 nautical miles.

Secondary Mission. The C-1B launch vehicle in the three-stage configuration shall place the Apollo spacecraft into a trajectory simulating lunar re-entry.

Other Missions. The C-1B launch vehicle will provide an early means of demonstrating the capability of the S-IVB stage in support of the C-5 Apollo program. In addition, the following missions may be performed:

(a) Two-stage Apollo re-entry.
(b) Earth orbital rendezvous (EOR) missions.
(c) Three-stage to escape missions.

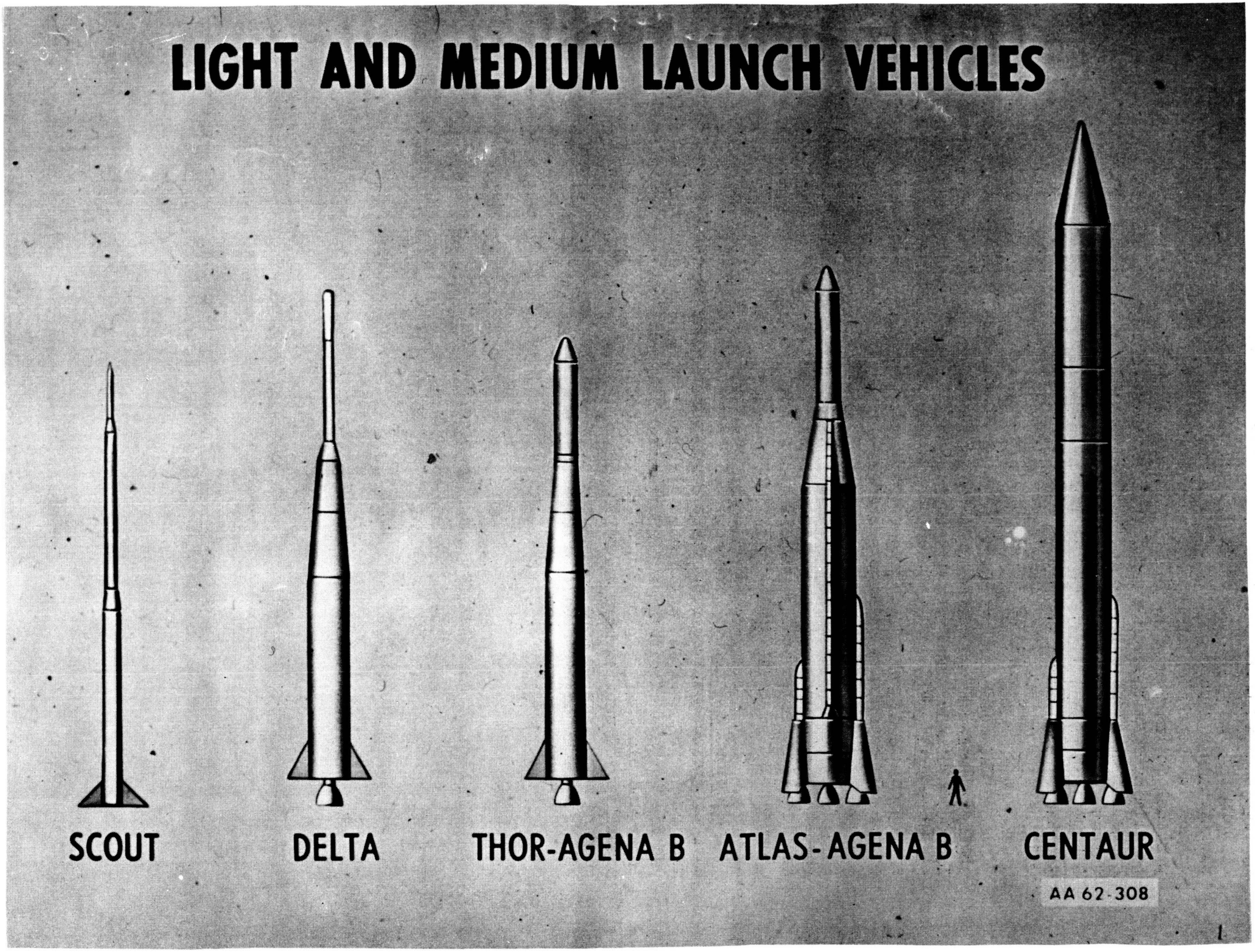
ADVANCED SATURN

Description: The Advanced Saturn first stage (S-1C) will be powered by five Rocketdyne F-1 engines, each of which develops 1.5 million pounds of thrust for a total thrust of 7.5 million pounds. The engines will be arranged in a square pattern of four gimballed engines with one fixed engine in the center of the square pattern. This basic configuration provides for maximum flexibility in that two of the outside engines can be eliminated without redesign, thus providing a more economical stage for missions which do not require the full 7.5 million pounds of thrust. The S-1C will have a propellant capacity of approximately 4.4 million pounds consisting of liquid oxygen and hydrocarbon fuel in two tanks, each approximately 33 feet in diameter. The total length will be approximately 138 feet.

The second stage (S-II) will be powered by five J-2 engines developing 200,000 pounds thrust each, for a total thrust of 1,000,000 pounds. The propellant (liquid oxygen and liquid hydrogen) capacity will be in excess of 900,000 pounds. The second stage will be approximately 33 feet in diameter and approximately 83 feet long. An engine-out capability will be provided.

The third stage (S-IVB) will use one J-2 engine for a total thrust of 200,000 pounds. It will carry 230,000 pounds of liquid oxygen and liquid hydrogen usable propellant loading and will be 260 inches in diameter and 58 feet long.

Mission Capability: The Advanced Saturn Launch Vehicle system will have sufficient payload capability to perform manned lunar-landing missions using a single earth-orbital rendezvous. Also, provide a basic vehicle for manned circumlunar and lunar orbit missions, and for unmanned lunar and planetary explorations. This launch vehicle will have the capability of putting more than 100 tons in a low earth orbit and of sending more than 40 tons to the vicinity of the moon. Prime emphasis will be placed on the Apollo, Prospector, and Voyager missions.


LIGHT AND MEDIUM LAUNCH VEHICLES
SCOUT
DELTA
THOR-AGENA B
ATLAS-AGENA B
CENTAUR
AA 62-308

COSTS OF LAUNCHED SPACECRAFT (MILLIONS OF DOLLARS)

Orbiting Astronomical Observatories

Spacecraft	(5)*	$ 181.4
Atlas-Agena	(5)	69.0
Total		$ 250.4

Unit cost $50.08 million

Orbiting Geophysical Observatories

Spacecraft	(9)*	$ 168.0
Atlas-Agena	(5)	38.7
Thor-Agena	(4)	23.3
Total		$ 230.0

Unit cost $25.6 million

Orbiting Solar Observatories

Spacecraft	(7)*	$ 48.0
Delta	(7)	17.5
Total		$ 65.5

Unit cost $9.36 million

Ionosphere Satellites

Spacecraft	(8)*	$ 10.673
Scout	(5)	5.000
Delta (Dev. Veh)	(1)	2.500
Thor Agena	(2)	13.100
Total		$ 31.273

Unit cost $3.9 million - Does not include spacecraft cost funded by International Groups.

Atmosphere Structures

Spacecraft	(3)*	$ 10.282
Delta	(3)	7.500
Total		$ 17.782

Unit cost $5.6 million

Energetic Particles Satellites

Spacecraft	(2)*	$ 4.462
Delta (Develop. Vehicles)	(2)	5.000
Total		$ 9.462

Unit cost $4.7 million

Probes

IMP

Spacecraft	(7)*	$ 12.470
Delta	(7)	17.500
Total		$ 29.970

Unit cost $4.2 million

SOLAR

Spacecraft	(4)*	$ 61.600
Atlas Agena	(4)	32.600
Total		$ 94.200

Unit cost $23.6 million

PIONEER

Spacecraft	(4)*	$ 18.100
Delta	(4)	10.000
Total		$ 28.100

Unit cost $7.0 million

Ranger

Spacecraft	(14)*	$ 150.126**
Atlas Agena	(14)	110.000
Total		$ 260.126

Unit Cost $18.6 million

Surveyor Lander

Spacecraft	(17)*	$ 255.949
Centaur	(17)	157.300
Total		$ 413.249

Unit cost $24.3 million

Mariner R

Spacecraft	(4)*	$ 58.526
Atlas Agena	(4)	32.800
Total		$ 91.326

Unit cost $22.8 million

Mariner B

Spacecraft	(5)*	$ 200.915
Centaur	(5)	47.000
Total		$ 247.915

Unit cost $49.6 million

Mariner M

Spacecraft	(2)*	$ 51.200
Atlas Agena	(2)	16.400
Total		$ 67.600

Unit cost $33.8 million

* Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

** Includes charges carried over from VEGA Development.